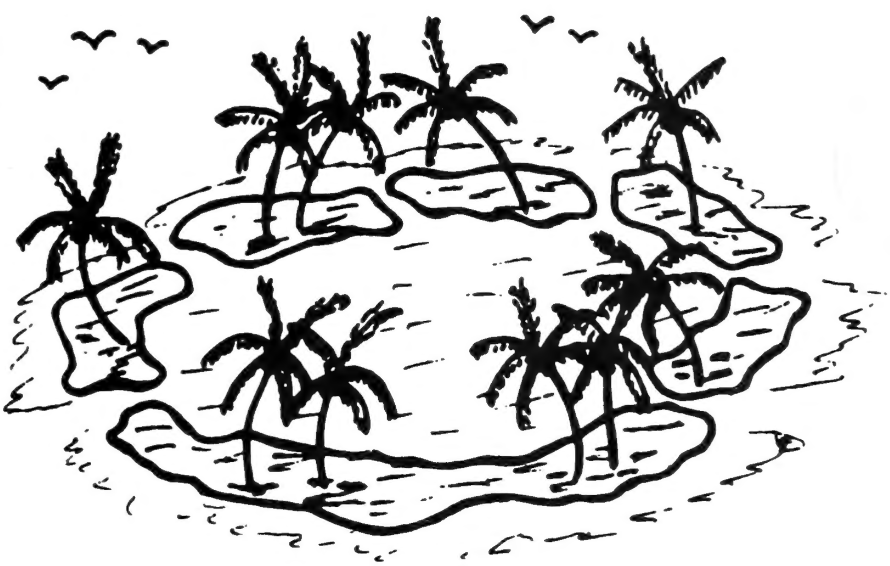
NOS. 193-205

ATOLL RESEARCH BULLETIN



Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

ATOLL RESEARCH BULLETIN

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

ACKNOWLEDGMENT

The Atoll Research Bulletin is issued by the Smithsonian Institution as a part of its Tropical Biology Program. It is co-sponsored by the Museum of Natural History and the Smithsonian Press. The Press handles production and distribution. The editing is done by the Tropical Biology staff, Botany Department, Museum of Natural History and by D. R. Stoddart.

The Bulletin was founded and the first 117 numbers issued by the Pacific Science Board, National Academy of Sciences, with financial support from the Office of Naval Research. Its pages were largely devoted to reports resulting from the Pacific Science Board's Coral Atoll Program.

ATOLL RESEARCH BULLETIN

NO. 193.

A PHOTOGRAPHIC SURVEY DOWN THE SEAWARD REEF-FRONT OF ALDABRA ATOLL

by Edward A. Drew

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

Contents

Figures (following p. 7)

Plates

A PHOTOGRAPHIC SURVEY DOWN THE SEAWARD REEF-FRONT OF ALDABRA ATOLL

by Edward A. Drew[1]

SUMMARY

A simple photographic transect method, using aqualung diving techniques, is described, together with an assessment of its limitations and possible improvements.

Data obtained from analysis of a 250 metre long transect (0 - 40 metres depth) photographed on the seaward reef-front of Aldabra Atoll are presented. Results are discussed in the context of previous reef zonation data and the possible environmental factors controlling such zonation.

INTRODUCTION

The upper 20 metres of the seaward reef-front of any barrier, fringing or atoll coral reef has until recently been impossible to investigate thoroughly due to prevailing sea conditions so close to the reef ridge.

However, in recent years the introduction of self-contained diving equipment, and care in selection of the season for field work to coincide with moderately calm conditions, have allowed a considerable amount of direct observational data to be acquired in this environment.

Nevertheless, such investigations tend to use a variety of ecological methods, mostly qualitative, and still "much of the difficulty in comparing reefs stems from the lack of uniformity in surveying methods" (Stoddart, 1969a).

In this paper a simple method of photographic recording down a reef transect is described and the results from its use on the most luxuriant section of the Aldabra reef-front are presented. The field work can easily be carried out by divers with no training in coral taxonomy and could be applied to any reef system, giving a standard basis for valid comparisons.

---

[1] Gatty Marine Laboratory, St. Andrews, Fife, Scotland.

(Manuscript received May, 1970--Ed.)

METHODS

Establishment of the transect

This was marked by a string, knotted with a loop at one metre intervals. It was laid down in 50 metre sections from the reef ridge (mean low water springs - MLWS) to the beginning of the basal sand plain at 40 metres depth. The string totalled 253 metres in length and was orientated approximately perpendicular to the shore-line although some meandering occurred in the extensive shallow parts. Each end was marked with a small buoy and these were triangulated from the shore; bearings are shown on the inset of the map in Figure 1.

Depth was recorded at 10 metre intervals using an 'SOS' totally enclosed bourdon tube gauge, and corrected to depth below MLWS according to the state of the tide.

An attempt to assist diver orientation on the very long transect by placing numbered polystyrene floats on short strings at 10 metre intervals proved unsuccessful. The film of algae (diatoms?) which rapidly developed on these floats was attractive to the browsing fish population which rapidly consumed most of the floats completely.

Photography

Standard 'Calypsophot' and 'Nikonos' underwater cameras with 35mm wide angle lenses were used to photograph the transect every metre from a distance of approximately 2 metres from the bottom. The open frame viewfinder of the cameras was used to align the camera as shown in Figure 2. Considerable overlap was achieved in all frames.

Monochrome 35mm film was used - Kodak Plus X (125 ASA) for most of the transect photographs, replaced by Ilford HP3 (400 ASA) in the deeper sections. No artificial lighting was used. The wide aperture setting required in the 30 - 40 metre section resulted in considerable loss of resolution in many of those frames.

Films were developed in the field, using a daylight-loading developing tank and cooling solutions in the refrigerator to about 20°C before use. In this way it was possible to ensure complete coverage of the transect with usable negatives.

Although several photographic dives were carried out on the transect, a large proportion of the usable exposures were made on a single dive of two hours duration. Three cameras were used, and each was reloaded twice in the boat, giving a total of over 300 frames.

The best negative for each metre section was printed to 12.5 x 20 cm (5" x 8") in the laboratory in the United Kingdom, using 'Ilfoprint' materials followed by hypo fixation and high gloss finishing.

Analysis of photographs

Sequential prints were oriented and cut to produce complete but unduplicated coverage down the transect; strips of five prints were each analysed as follows.

Code numbers were allocated to a total of 26 different coral growth forms and other recognisable organisms. Some of these were later lumped together and final analysis involved the following groups:

Cymodocea (marine angiosperm)	Alcyonacean (soft coral)
Branching coral	Gorgonian
Columnar coral	Halimeda algae (+ traces Caulerpa)
Brain coral	Sponges
Foliaceous/encrusting coral	Tridacna clams
'Pioneer' coral	Anemones
Fungia coral	Uncolonised bare areas

Encrusting calcareous red algae could not be distinguished on the photographs although they represented a significant part of the living cover in some sections. The organisms and coral types involved are illustrated in a representative selection of frames in Plates 1 and 2.

The outlines of the various colonies in each set of five contiguous prints were traced onto high quality tracing paper (uniform density) and the appropriate shapes were cut out and weighed. In this way the area of each 5 metre transect section covered by a particular growth type was determined. No attempt was made to allow for differing colony morphology and therefore actual surface area of living coral which in some instances would be several times greater than the area photographed. In view of the great importance of the symbiotic algae present in the coral organisms, it seems probable that the area exposed to direct solar illumination will be of major importance in their growth.

RESULTS

The topography of the transect studied is shown in Figure 3, together with an analysis of the percentage cover of living organisms on both a horizontal and a vertical basis.

This particular transect, the longest of a total of 12 accurately surveyed around the atoll (see Figure 1), provided two contrasting environments. Firstly there was an extensive shallow region where the major variable factor appeared to be

proximity to the reef ridge surf zone, followed by a region of moderately rapid increase in depth until the growth of hermatypic corals ceased at the start of the basal sand plain. This last appeared to slope away indefinitely at an angle of about 20^{o} from horizontal.

Analysis according to depth has been carried out by averaging the various series of prints included in each 2 metre increment of depth. Percentage living cover remains remarkably constant until below 30 metres, when it drops rapidly to a much lower value.

The regular alternation between high and low cover values shown in the horizontal analysis is due mainly to a series of completely bare areas, on a scale several times greater than the size of a photographic frame. These were either bare coral rock or depressions filled with coral debris (mainly branching types) in shallow water but sandy in deeper parts.

The distribution of the various growth types with depth is illustrated in Figure 4, again averaged for the series of 5 metre strips included in each 2 metre depth increment. Uncolonised bare areas have been disregarded in this analysis which shows the percentage of the living cover represented by each type. There is a marked zonation, with the branched and less massive types in shallow water and the massive brains much deeper. Alcyonacean soft corals were intermediate in distribution whilst only the foliaceous and encrusting types occurred in the deepest parts. The significance of this zonation will be discussed later; representative strips from the major zones are shown in Plate 3.

Additional information about the response of the shallow water types to surf action has been obtained by analysis of the first 60 metres of the transect horizontally, this being restricted to the upper 2 metres of the depth range. Heavy surf is unlikely to occur far seaward of low water mark. Figure 5 shows such a horizontal analysis which indicates restriction of the millipore corals to the maximum surf zone whereas branching corals formed a small part of the total cover until some 25 metres from MLWS. Columnar corals were relatively unimportant and showed little correlation with distance from MLWS, but the restriction of the Alcyonaceans to the most distant part suggests that they are relatively sensitive to severe water movement.

OTHER TRANSECTS

In order to put this transect into perspective compared with other areas of the Aldabra reef-front, the 14 transects surveyed around the atoll are shown in Figure 1. Only transect topography and the approximate coral cover were determined on all but transect 1, the photographic transect. The submarine

contours shown are greatly exaggerated compared with the scale of the atoll outline. Also shown is the vertical extent of reef-front rocky substrate before the beginning of the basal sand plain.

The north-west part of the reef-front was the only region with luxuriant coral growth, that along the north shore was generally poor, and that on the south had apparently recently suffered a major catastrophe with the dead remains of apparently good growth evident in several places. The eastern end of the atoll had no coral reef front, but rather a very gently sloping sand plain from MLWS.

DISCUSSION

Initial structural considerations would suggest that branching corals of the millepore and acropore types are less well suited to the rigours of shallow water reef-front environments than are the more massive brain corals. Indeed, Stoddart (1969a) cites numerous references to the occurrence of fragile-branching types on lagoon reefs and in sheltered pools, whilst stout-branching and more massive types are concentrated on reef flats and upper seaward slopes.

The data presented in this paper suggest the opposite for the luxuriant section of Aldabra reef-front, a situation also noted by Stoddart (1966, 1969b) in the Maldives and the Solomons where "reefs consist largely of foliaceous and fine branching forms even in exposed situations". This feature of reef zonation may be due to the rarity of severe storms in these three regions. The north-west tip of Aldabra is nevetheless completely exposed to oceanic swell and receives a considerable pounding by waves for much of the year. Taylor (1968) also reports dominance of millepore/acropore types in exposed situations on Seychelles reefs, but with massive species dominant in sheltered areas.

The restriction of millepore corals to the heavy surf region of the reef-front may be associated with the same factor which allows their predominance in the fast-flowing channels leading into Aldabra's extensive but very shallow lagoon, perhaps a requirement for constantly moving water or an ability to withstand the relatively warm water which flows both off the reef flat and out of the lagoon. Taylor (1968) suggests that the vertical inter-connected plates which comprise the surf-zone millepore colonies are well adapted to absorb the energy of breaking waves, but it is also necessary to explain their virtual absence in stiller water.

Foliaceous forms of coral are well suited to intercept a maximal amount of available light with a minimum volume of colony, and are thus well suited to the deep dim waters where they predominated on this transect. It is however surprising that the total living cover of the reef remained reasonably

constant until the very rapid reduction below 30 metres. There was even a noticeable increase between 15 and 25 metres. Thus, living cover does not appear to be correlated directly with ambient light energy - the two are compared in Figure 6 - although the interrelations between growth type, efficiency of light utilisation, rate of primary organic production and rate of calcification are as yet only known in the barest outline. Important too may be the preferences of coral browsers such as parrot fish, and their ability to feed in turbulent shallow water.

The simple photographic transect method described here could provide a basis for rapid accurate assessment of various types of reef and allow valid quantitative comparisons. The method has certain limitations in accuracy, such as the edge distortion produced by uncorrected wide angle lenses, although most of this is eliminated by cutting off the extremities of each print for overlap. The expense of using the 28mm corrected underwater lens available for the Nikonos camera is probably unwarranted, especially as several separate cameras are required for long transects (see later).

Recognition of various growth forms proved moderately easy with the monochrome prints used, although artificial illumination would have allowed increased definition in deep sections whilst the use of colour print film should in future allow positive identification of most species, including the encrusting calcareous red algae, as well as a further increase in definition. Unfortunately the prints from colour transparencies usually lack the sharpness required for this work.

Phototransect methods could also be used in the rapid topographic survey method used on the majority of transects studied in Aldabra. This involved two divers, separated by a 10 metre length of string, leap-frogging each other in a straight line down the reef and recording depth every 10 metres. A third diver could photograph the ten metre strip in 1 metre sections whilst the surveyors recorded their own data. This would require six cameras for a long transect - say 200 metres - and may double the survey time. However, the vast increase in data obtained, and the saving in time required to establish semi-permanent transects and relocate them on each dive, would certainly justify this.

Finally, a note on diver safety. Coral reefs are frequently inhabited by potentially aggressive animals, mainly sharks. Fortunately these were virtually absent from the Aldabra reef-front at the time this survey was carried out (December, 1968 to February, 1969), so that divers could concentrate on their scientific tasks. It would, however, be essential for a survey team working in more dangerous waters to be accompanied by 'look-outs', perhaps involved in more random photography or collection of reef flora and fauna, but primarily there to allow the team to concentrate on their complex tasks knowing they will be warned of impending danger.

ACKNOWLEDGEMENTS

This work formed a small part of the diving programme of Phase VI of the Royal Society Expedition to Aldabra, and was made possible by the organisation and logistic support provided by the Aldabra Research Committee and the overall expedition leader, Dr. D. R. Stoddart.

I would also like to thank all the other members of that phase of the Expedition, and especially Dr. J. Lythgoe, Mr. D. Jones and Mr. J. Barnes who accompanied me on most of the photographic and survey dives, for their help in the field.

The Court of St. Andrews University generously granted me leave of absence for this expedition.

REFERENCES

Bellamy, D., Drew, E., Jones, D. and Lythgoe, J. 1970. Aldabra - a preliminary report of the work of Phase VI of the Royal Society Expedition. Underwater Ass. Report 1968-69.

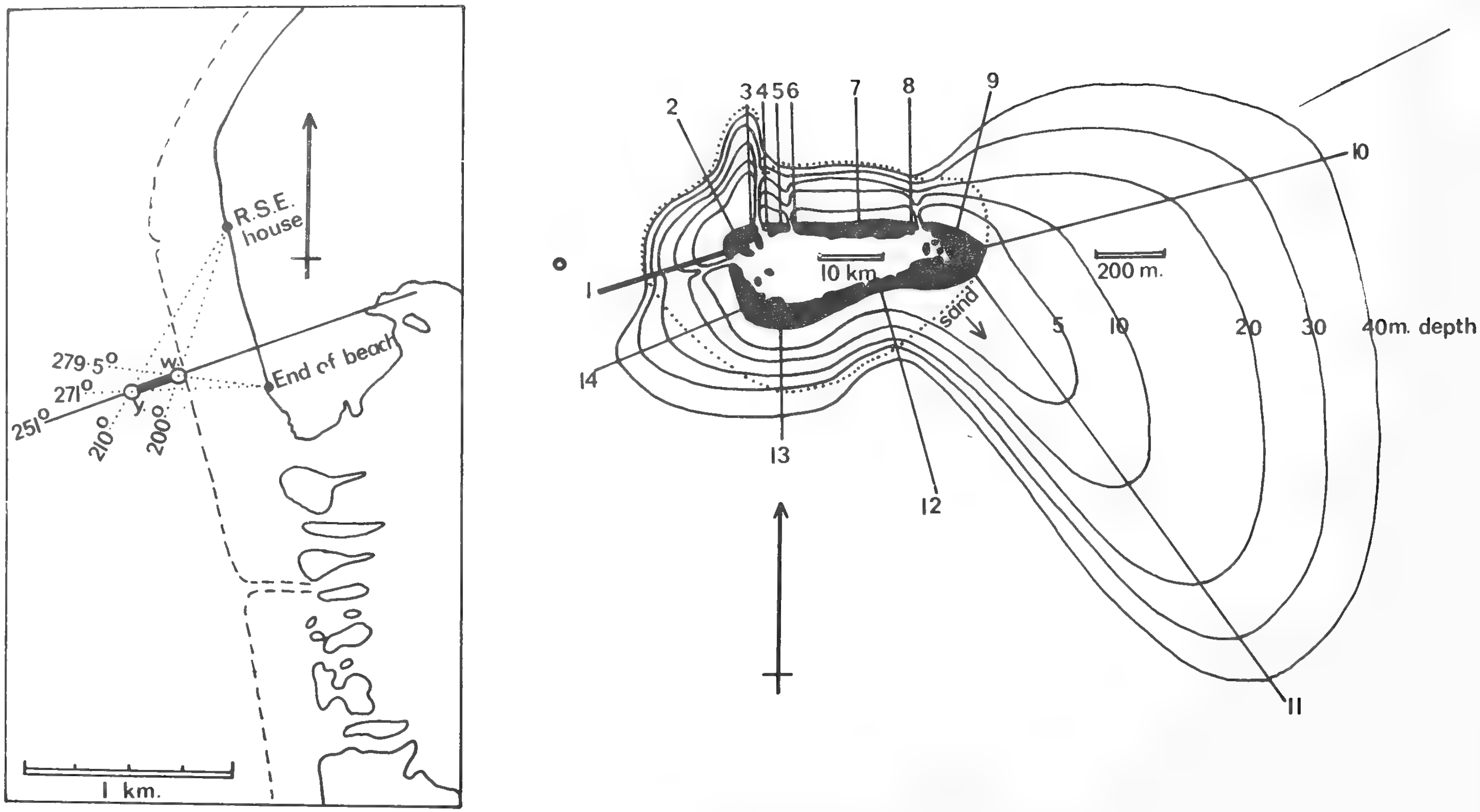
Stoddart, D.R. (Editor). 1966. Reef studies at Addu Atoll, Maldive Islands. Atoll Res. Bull. 116: 1-122.

Stoddart, D.R. 1969a. Ecology and morphology of Recent coral reefs. Biol. Rev., 44: 433-498.

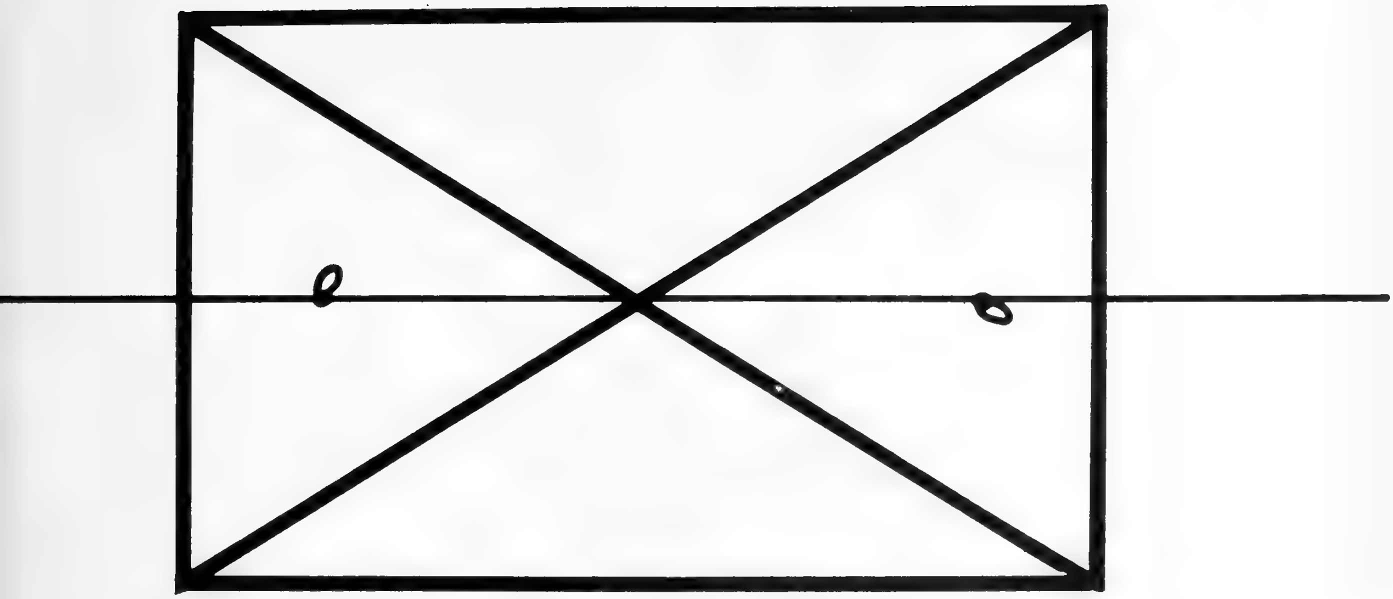
Stoddart, D.R. 1969b. Geomorphology of the Marovo barrier reef. Phil. Tran. Roy. Soc. B. 255: 383-402.

Taylor, J. 1968. Coral reef and associated invertebrate communities around Mahé, Seychelles. Phil. Trans. Roy. Soc. B. 254: 129-206.

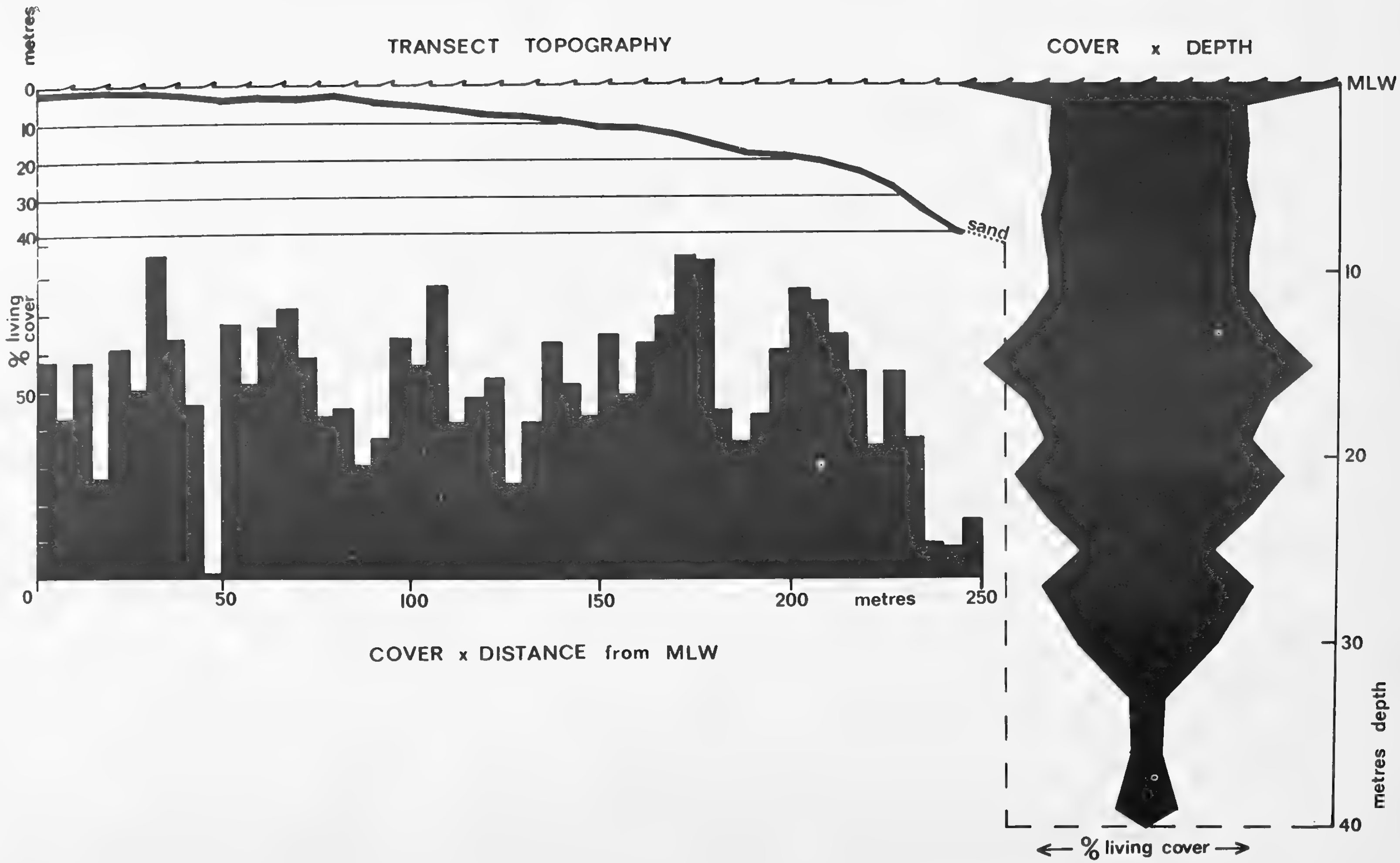
Figures



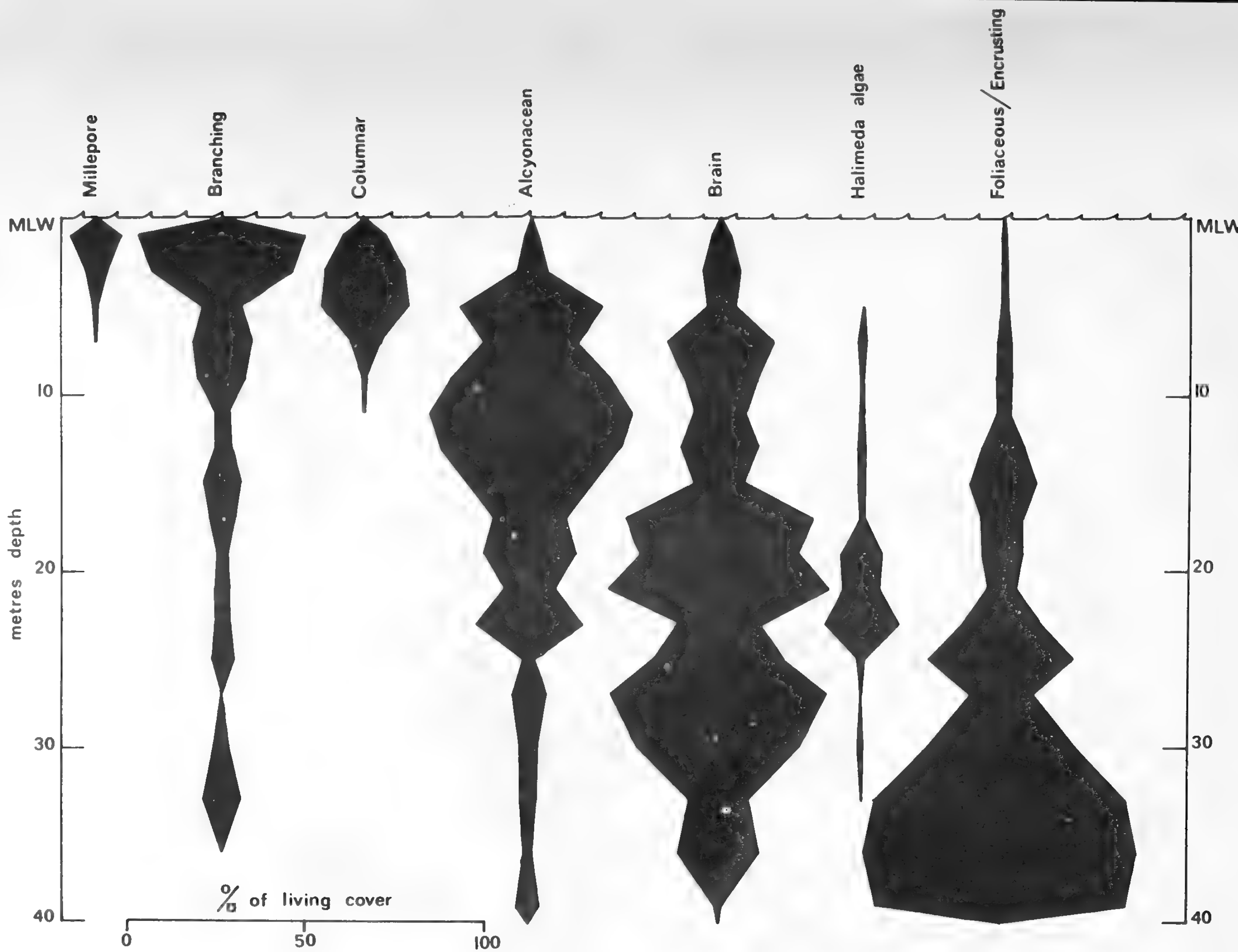
1 Aldabra Atoll, showing location of all transects and implied submarine contours (modified from Bellamy et al, 1970)



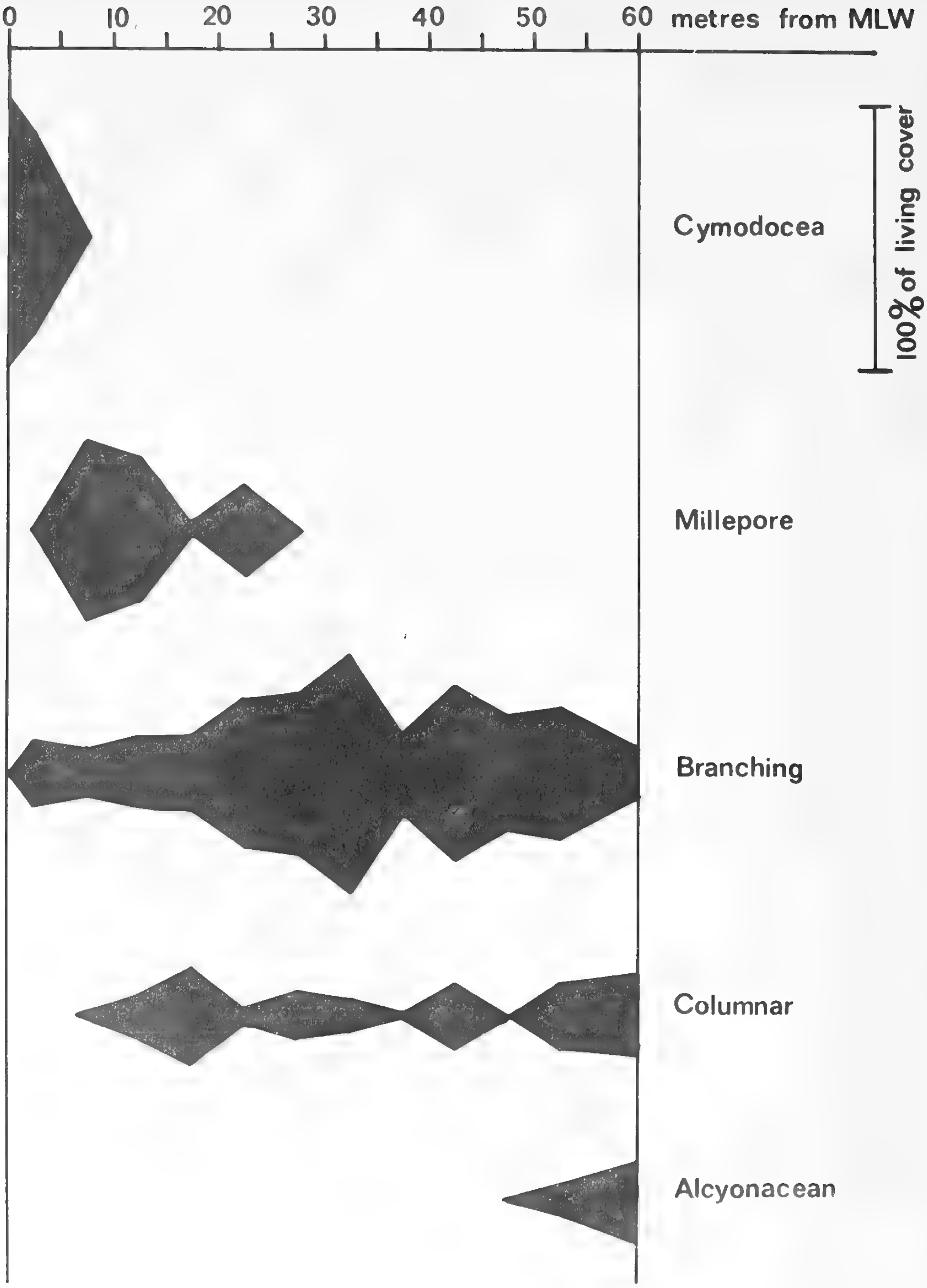
2 Camera orientation on photographic transect



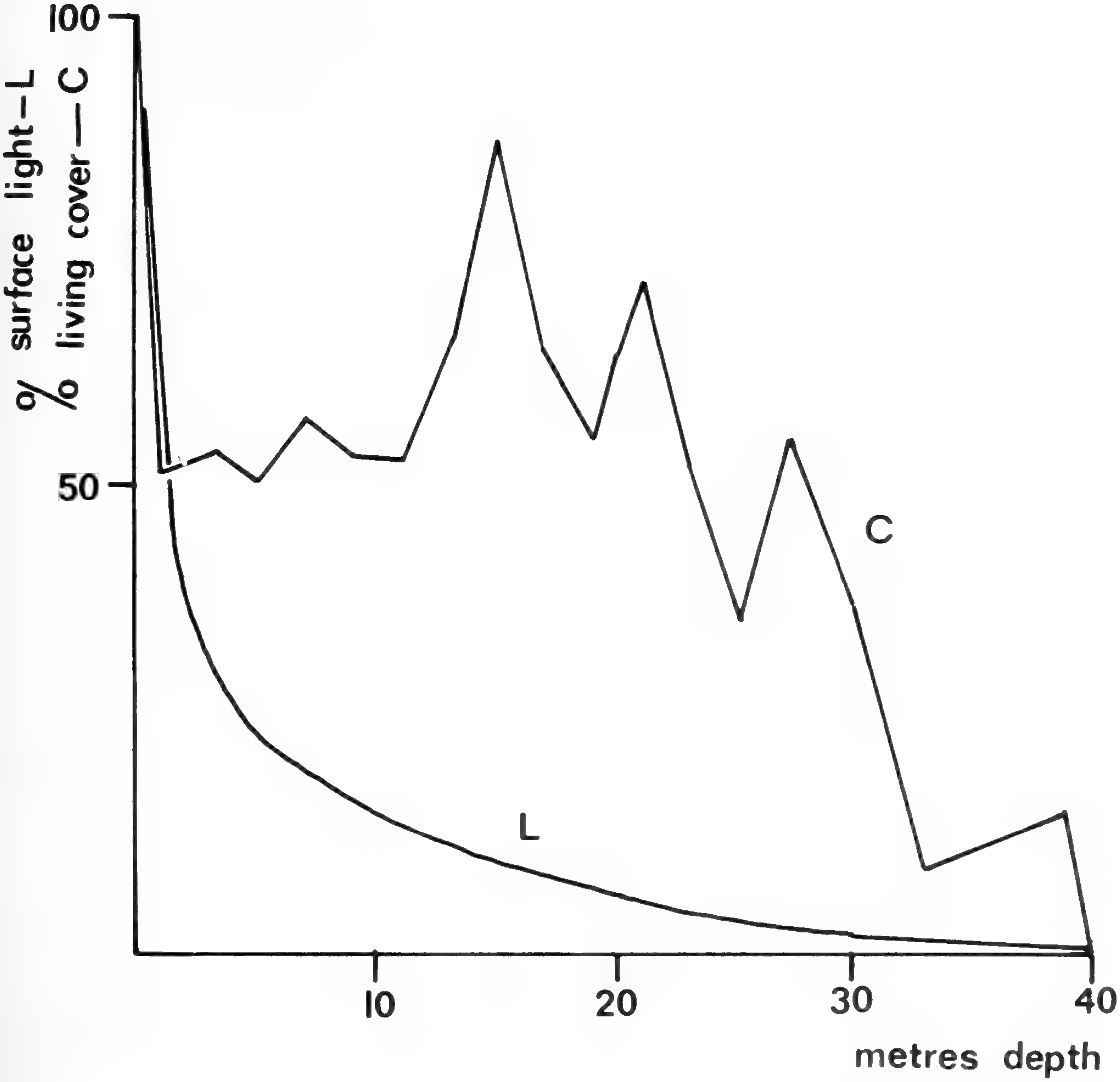
3 . Transect topography and percentage living cover



4 Depth distribution of various growth types

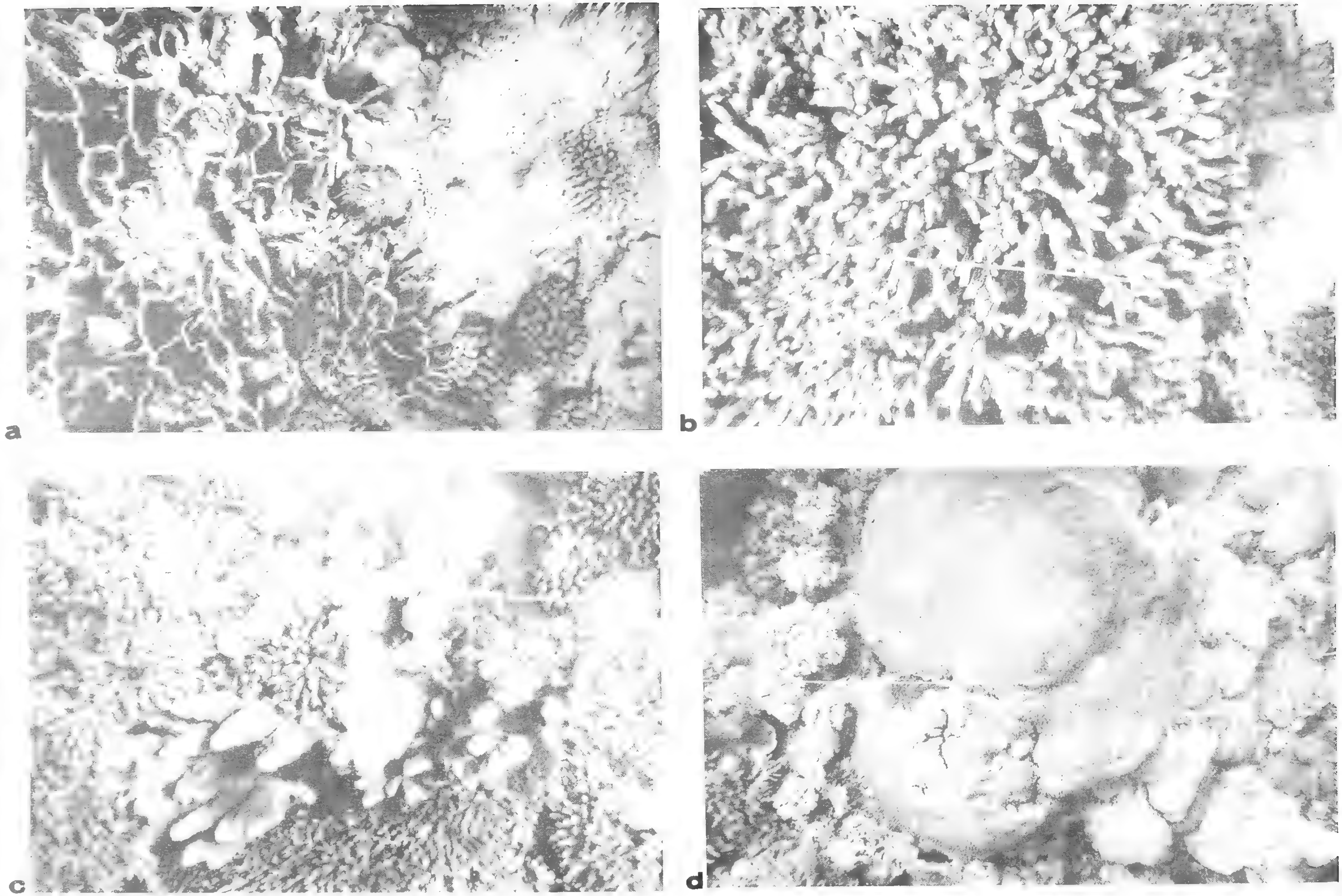


5 Horizontal distribution of growth types away from surf zone



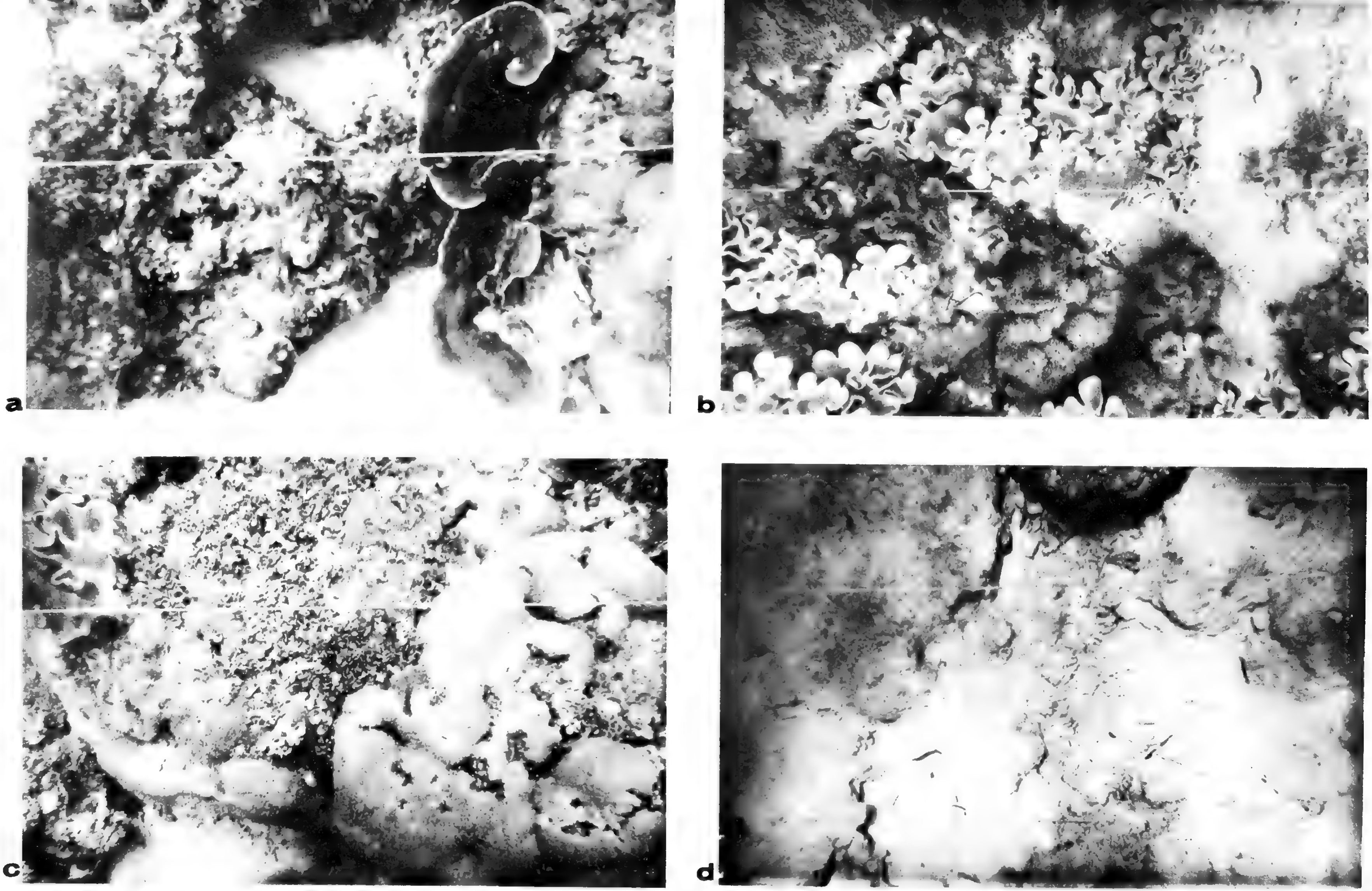
6 Submarine light intensity and percentage living cover

Plates



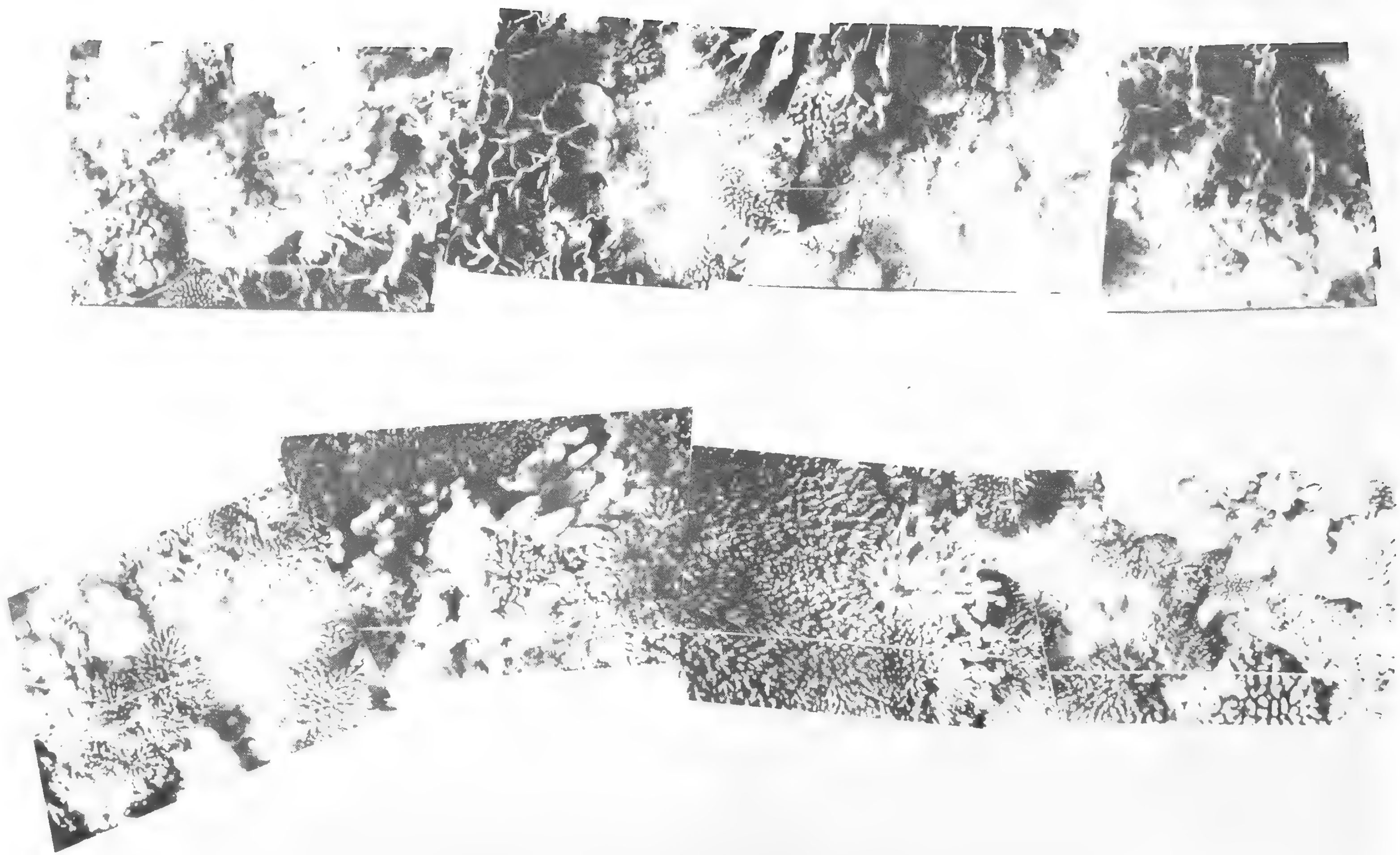
1 Phototransect frames illustrating growth types discussed

a. Millepore
b. Branching coral
c. Columnar coral
d. Brain coral



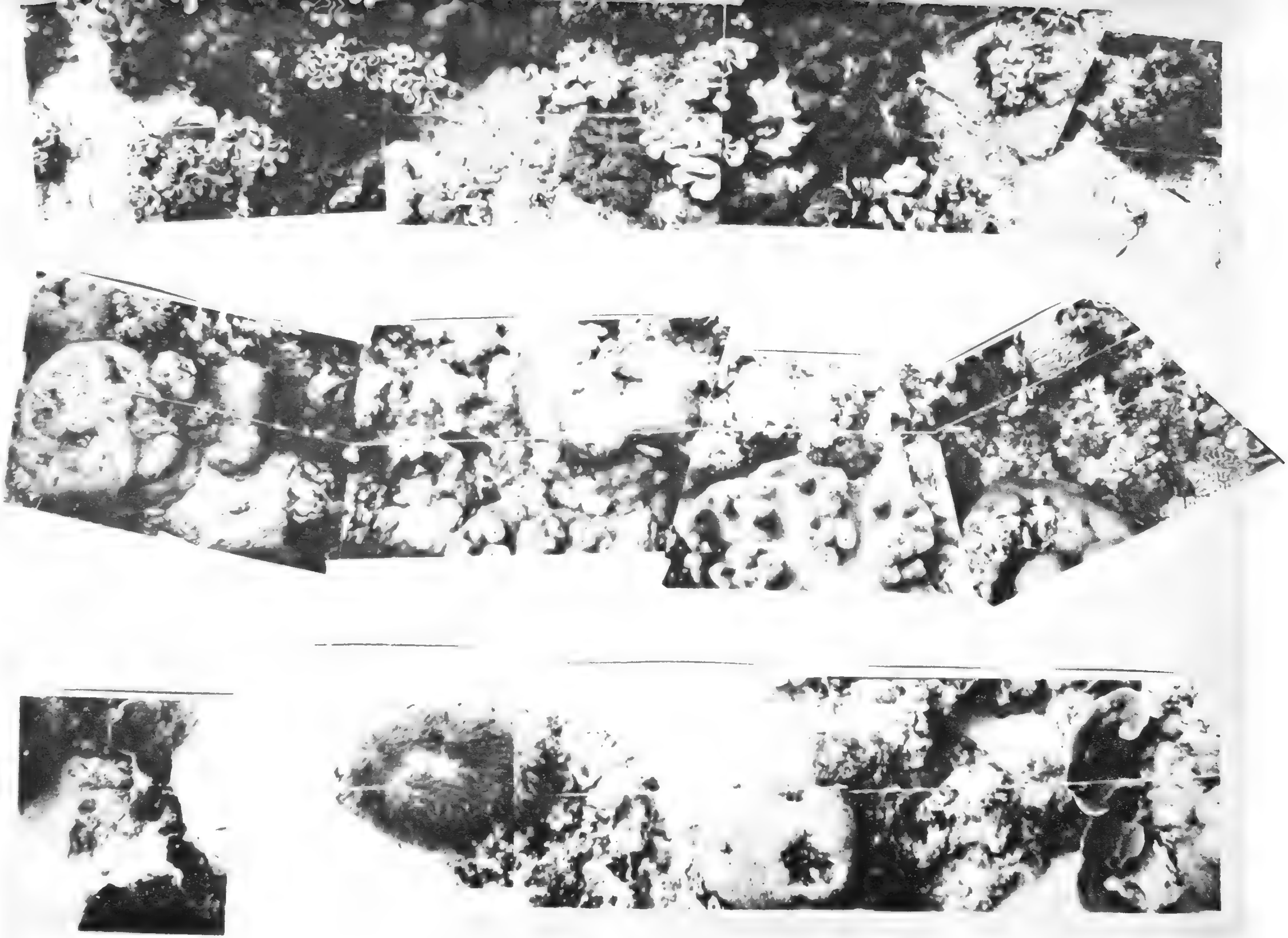
2 Phototransect frames illustrating growth types discussed

a. Foliaceous coral
b. Alcyonacean soft coral
c. *Halimeda* algae
d. Uncolonized bare areas



3 Representative strips from various important zones

a. Millepore coral zone
b. Branching coral zone



c. Alcyonacean soft-coral zone
d. Brain coral zone
e. Foliaceous coral zone

Contents

TOPOGRAPHY AND CORAL DISTRIBUTION OF BUSHY AND REDBILL ISLANDS AND SURROUNDING REEF, GREAT BARRIER REEF, QUEENSLAND

by Carden C. Wallace[1/] and E.R. Lovell[2/]

INTRODUCTION

The following description presents information obtained by the authors over a ten day period, 26 December 1972 to 4 January 1973. The purpose of this paper is to provide an introduction to an area which was previously unstudied, as an aid to further investigation.

Locality: The area studied is located on the inner shelf of the Great Barrier Reef Province, southern region, latitude 20° 57'S, longitude 150° 5'E. This is approximately 92 km ENE of Mackay, on the Queensland coast (see inset, fig.1).

Orientation and size: The reef is oval, its long axis running NNW to SSE. Maximum length is approximately 6 km, and width 4 km. Surrounding water depth ranges from 26 m to 54 m.

Winds and rainfall: The main wind influence is east-southeasterly to southeasterly and continues throughout the year (see inset, fig.1). Rainfall at nearby Pine Islet averaged 3478 points per year in the period 1935-1973, the highest falls being in January to March (information from the Australian Bureau of Meteorology).

Tidal range: The reef lies within a zone of high tidal range, this being approximately 5 m (taken by extrapolation from Maxwell 1968, fig.42).

Other descriptions of the area: The reef and islands are described briefly in the Australia Pilot Vol.IV (1962). Bushy Island is mentioned and figured by Steers (1938), who visited the area during rough weather and made a rapid survey. A collection of 23 coral specimens, comprising 7 species, in the

---

[1/] Queensland Museum, Gregory Terrace, Fortitude Valley, 4006, Queensland, Australia.

[2/] Zoology Department, University of Queensland, St. Lucia, 4067, Queensland, Australia.

(Manuscript received September 1973--Eds.)

Great Barrier Reef Committee collections at the Queensland Museum is labelled "Redbill Reef, coll.: Geranium". This was apparently obtained from the reef flat adjacent to Redbill Island by Charles Hedley in 1924 (see Hedley, 1925, and also Appendix 1, this paper).

TOPOGRAPHY

The Islands

Orientation, structure and size: The islands are situated on the western edge of the reef, Bushy Island 1.2 km NNW of Redbill. Redbill is a continental island, composed principally of alkali granite bisected by dykes of microdiorite and trachyandesite. It is approximately 21 m high and 1.6 hectares in area. Bushy Island is a coral cay, of area approximately 7.3 hectares, the beach crest being approximately 4 m above the inner reef flat. It is composed of coral sand, and a sand pit is developed at the NNE end of the island. A ridge of beach rock extends along the E-SSE edge (see fig.2), not on the SW side as recorded by Steers (1938).

Terrestrial vegetation: Species lists of plants from both islands are given in Appendix 2. Nineteen species were recorded from Bushy Island, with three predominating. The extent of the dominants is shown in fig.2. The most prevalent species, in terms of area occupied, is *Pisonia grandis*. The *Pisonia* forest excludes other species except on its margin. *Pandanus* sp. extends as a continuous margin along the western perimeter of the *Pisonia* forest to the north east, and as clumps around the remainder of the island. Bordering this and extending to the beach is a band of *Tournefortia argentea*. Other conspicuous beach species are *Thuarea involuta*, *Ipomoea pes-caprae*, *Salsola kali* and *Scaevola taccada*.

The Reef

Methods: Observations were made along transect lines at right angles to the reef edge (see fig.1). Lines were worked variously by walking out at low tide, by skin diving and by diving with compressor unit from a small boat, depending on accessibility and depth. Contour measurements were made with a graduated pole. As time and manpower were limited, many additional observations on the reef were made qualitatively in areas outside the transect lines.

Transect lines were marked in metres. The method of observation was to note coral species present within 15 cm on either side of the transect line in each metre segment. This was found to be a reasonably satisfactory way of covering a large cross-section of the reef for a preliminary study, although it is not proposed as an adequate or standard method for more detailed survey. Corals were recorded by presence

along the 1 m segment. In the early part of the survey, numbers of colonies were counted, individual colonies being defined as by Loya (1972). This method proved to be applicable in inner reef flat areas, but difficult to apply to the arborescent and layered-plate corals in outer areas. In cases where the species could not be separated in the field from related species, corals were identified to genus only. This was found to be necessary in genera such as Psammocora, Porites, and Montipora. A representative collection of corals was made, and these have been tentatively identified (see Appendix 1).

In qualitative work, as much as possible of the non-transect area was covered by walking out and diving, listing corals observed, and collecting specimens of each species. The sectors of the reef least observed were the outer lagoon and the eastern region (see fig.1).

The authors did not have sufficient opportunity (or facilities) to study the off-reef floor. Although the floor immediately adjacent to the reef front (8-12 m depths) was examined on three transect sites and in qualitative work, that beyond was not studied. It is hoped that this area can be the focus of further work on a return visit.

Reef structure: The reef can be regarded as consisting of a central region and three generalized surrounding regions. These can be seen in the aerial photograph (plate 1) and in fig.1.

1. The central region is generally lower than the surrounding regions, and has an inner and an outer lagoon. These reach low water depths of approximately 3 m, and have a sandy base, with scattered alcyonarian and coral growth in small patch reefs. In the non-lagoonal areas microatolls are developed, and coral growth is generally denser.

2. To the west of the central region is the region of the reef least exposed to prevailing winds. The largest zone in this region is an "inner flat" zone (in the terminology of Stoddart 1969) which extends between the islands, gradually merging with the central region in the east, and delimited by a series of green algal banks in the west. The algal flora of these banks has not yet been studied. A single bank approximately 40 m wide in the vicinity of Bushy Island breaks up into a series of narrow ledges at the tip of the Bushy Island sand spit, and into two main banks with ramifying small axillaries between Bushy and Redbill, these extending to the south west end of the reef (see fig.1). Beyond the algal banks is a "reef flat proper," which is widest in the NW and much reduced in the SW end of the region. A small lagoon is developed in this zone immediately SW of the sand spit. The "outer reef flat" in this western region is characterized by luxuriant alycionarian growth and sponges, as well as a diverse and luxuriant coral composition. This zone continues to the reef edge, where very dense

coral growth occurs uninterrupted down the face of the reef slope to the first part of the floor at approximately 10 m. A very open spur and groove system is developed in the reef front.

3. In the region most exposed to prevailing winds, zonation is somewhat different. The widest and innermost zone is one of dense microatoll development, the microatolls being very low (approximately 30 cm in height), and elongated in a direction at right angles to the reef edge. In some areas these structures have grown together to form a continuous pavement which crumbles easily underfoot. Beyond this is a shallow "inner flat" zone with oystercovered coral boulders, and some special characteristics (such as the presence of the commercial trochus Trochus (Rochia) niloticus). This is followed by a zone of consolidated coral rubble and sand, with green algal covering, possibly analogous to the algal banks mentioned previously, but wider and more gradually sloping. Scattered coral colonies appear in this zone towards the reef edge and a narrow reef flat zone at approximately mean low water mark bordered by the reef edge is apparently analogous to the "algal ridge" of other reefs - coral cover is low but dense, of corymbose and encrusting forms, with Acropora cuneata in low vertical plates perpendicular to the reef edge (see plate 3). The reef front in this area drops as a series of terraces, between which the floor is studded with coral boulders. A spur and groove system is developed, the grooves often being secondarily overgrown, forming long slits in the reef.

4. The eastern side of the reef was the least investigated, but in the vicinity of transect 6 (NNE end of reef) it was seen to combine features of the leastexposed and the most-exposed regions. A very wide sandy "inner flat" is separated by broken algal banks from a relatively barren outer flat, then a zone of flattened coral growth, followed by luxuriant coral growth on the reef front to the floor at approximately 8 m, where large coral-covered knolls occur.

CORAL DISTRIBUTION

Distributions are variously described, depending on the methods and intensity by which zones were studied. The study concentrated on Scleractinia, but Millepora and Tubipora have been included.

"Inner Flat" Zones:

Table 1 gives coral occurrences in sections of transects running through "inner flat" zones. The zone is characterized by a small number of species, the commonest being the massive Porites (mainly P. lutea), Goniastrea australensis and Acropora palifera. (Note: The classification of Wijsman-Best (1972) is followed for Faviid species. The authors suspect that a

thorough taxonomic study of A. palifera and A. cuneata may prove them to be a single species.)

Algal Banks

The only corals occurring on the green algal banks were occasional very small encrustations of the "inner flat" species, in particular Porites, Goniastrea and Favites.

Lagoons

No lagoonal transects were made, but the following species were recorded from patch reefs within the lagoons:

Pocillopora damicornis
Seriatopora hystrix
Stylophora mordax
Acropora digitifera
A. palifera
A. hyacinthus
A. cf. syringodes
Montipora (plate and branching species)
Astreopora myriopthalma
Fungia actiniformis
F. fungites
Porites (massive and branching species)
Goniopora tenuidens
Montastrea curta
Favia speciosa
Favites abdita
F. virens
Goniastrea pectinata
Platygyra lamellina
Cyphastrea serailia
Echinopora lamellosa
Leptastrea purpurea
Lobophyllia corymbosa
Acanthastrea echinata
Symphyllia nobilis
Millepora exaesa
M. tenera

Microatoll Zone of the Central Region

No transects were made in the microatoll zone, but the following species were recorded:

(a) forming microatolls:

Seriatopora hystrix
Porites andrewsi
Porites sp. 1 and 2 (branching)
Acropora palifera forma a
Pavona frondifera

Table 1. Comparison of coral occurrences in "inner flat" zones, expressed as % of total metre segments in which the coral occurs

Species	Transect 1 (length 172m)	Transect 2 (length 94m)	Transect 3A (length 98m)	Transect 3B (length 97m)	Transect 5 (length 46m)
Porites (P. lutea, P. lichen, P. annae)	35	28	8	33	4
Goniastrea (G. australensis, G. pectinata)	35	39	4	21	11
Acropora palifera	12	31	4	4	0
A. digitifera	6	21	2	0	0
Pocillopora damicornis	5	13	9	2	0
Tubipora musica	0	12	3	2	0
Favites abdita	1	0	0	0	7
Goniopora tenuidens	1	0	0	0	0
Symphyllia nobilis	0	0	0	0	2

(b) occurring on and around microatolls:

Millepora exaesa	*P. daedalia*
Goniastrea australensis	*P. sinensis*
G. pectinata	*Acrhelia horrescens*
G. retiformis	*Tubipora musica*
Porites (massive species)	*Acropora spicifera*
Leptastrea purpurea	*A. hebes*
Goniopora tenuidens	*Fungia actiniformis*
Pocillopora damicornis	*Symphyllia nobilis*
Cyphastrea serailia	*Favia speciosa*
Platygyra lamellina	*F. pallida*

Microatoll Zone of the most exposed Region

This zone was also not studied in detail, but the structural basis of the microatolls was seen to be provided by *Acropora palifera* forma *a*.

"Reef Flat Proper"

The only area corresponding to this zonation studied was in the vicinity of Transect 2, and was seen to be of similar coral composition to the "inner flat" zone, although depth was greater.

"Outer Flat" Zone

The whole "outer flat", to the edge of the reef, is here treated. Table 2 compares coral representation in three transects. The comparative lengths of the transects should be noted.

Reef Slope

Four transects passing over the first part of the reef slope are compared in table 3. Those in the region of transects 2 and 4 were gently sloping (12 m slope to a depth of 10 m); those of transects 5 and 6 dropped sharply to the floor. Alcyonarians were most prevalent in the region of transect 2 (least exposed side of reef).

Floor adjacent to first part of Slope

In all four areas studied, this part of the reef was characterized by the presence of coral knolls. The most obvious scleractinians on these knolls are arborescent forms (including *Acropora intermedia*, *A.* cf. *acuminata*, *A. pulchra*, *Hydnophora rigida*), "bottle brush" forms (*Acropora exilis*, *A.* cf. *rosaria*,

Table 2. Comparison of coral occurrences in "outer flat" zones, expressed as % of total metre segments in which the coral occurs

Species	Transect 2 (length 287m)	Transect 5 (length 46m)	Transect 4 (length 59m)	Transect 6 (length 12m)
Porites (massive species)	31.0	69.0	42.5	50.0
Goniastrea (australensis and pectinata)	12.5	2.0	29.0	
Acropora cuneata and palifera	13.5	45.5	47.5	8.5
Favites (abdita, virens and flexuosa)	10.0	30.5	22.0	35.5
Pocillopora damicornis	10.0	32.5	5.0	25.0
Acropora humilis	8.0	32.5	27.0	8.5
Leptastrea purpurea	2.0	19.5	12.0	8.5
Montipora (several species)	2.0	11.0	5.0	16.5
Montastrea curta	1.0	2.0	1.5	16.5
Acropora hebes	6.0	22.0		
Seriatopora hystrix	14.0	17.5		
Symphyllia nobilis	2.0	26.0		
Stylophora mordax	12.0	8.5		
Platygyra (3 species)	5.0	13.0	42.5	

Table 2 cont'd.

Favia (*speciosa*, *pallida*)	5.0	13.0	39.0	33.5
Acropora cf. *syringodes*	4.0	11.0	47.5	8.5
Goniopora tenuidens	3.5	6.5	22.0	
Millepora sp.	2.0	8.5	5.0	33.5
Fungia fungites	0.5	4.5	27.0	
Acropora spicifera	0.5	4.5	12.0	25.0
Acrhelia horrescens	1.0	2.0	1.5	8.5
Coscinaria columna	0.5	2.0		
Echinophyllia aspera	0.5	2.0		35.5
Tubipora musica	6.0			
Euphyllia glabrescens	4.0			
Hydnophora exesa	3.0			8.5
Acanthastrea echinata	3.5			
Fungia scutaria	2.0			
Echinopora lamellosa	1.5			
Acropora intermedia	1.0			8.5
Acropora formosa	1.0			

Table 2 cont'd.

Species	Transect 2 (length 287m)	Transect 5 (length 46m)	Transect 4 (length 59m)	Transect 6 (length 12m)
Acropora cf. acuminata	1.0			
Acropora cf. clavus	1.0			35.5
Astreopora sp.	1.0			
Caulastrea furcata	1.0			
Echinopora gemmacea	0.5			
Oulophyllia crispa	0.5			
Favia stelligera	0.5			
Leptoria phrygia	0.5			
Turbinaria sp.	0.5			
Merulina ampliata		4.5		8.5
Acropora squamosa		4.5		
A. exilis		2.0		
Echinopora horrida		2.0		
Tubastrea sp.				16.5

Table 2 cont'd.

Cyphastrea serailia	8.5
Mycedium tubifex	25.0
Lobophyllia corymbosa	8.5
Acropora cf. *rosaria*	8.5

Table 3. Comparison of coral occurrences in reef slope zones, expressed as % of total metre segments in which the coral occurs

Species	Transect 2 (length 12m)	Transect 4 (length 12m)	Transect 5 (length 4m)	Transect 6 (length 8m)
Acropora cuneata	8.5	67.0		
Montipora (encrusting species)	50.0	25.0	75.0	
Favites sp.	33.5	33.5		
Acropora formosa		41.5		
Goniastrea australensis		33.5		
Leptastrea purpurea	25.0	16.5	50.0	
Porites (massive species)	16.5	8.5	50.0	25.0
Stylophora mordax	8.5	25.0	50.0	
Acropora variabilis	8.5	25.0		
A. humilis		41.5		
Goniopora tenuidens	8.5	16.5		37.5
Echinopora lamellosa	16.5	16.5		
Pocillopora damicornis	8.5	16.5	25.0	
Astreopora myriophthalma	25.0			

Table 3 cont'd.

Coscinaraea columna	25.0			
Cyphastrea serailia	16.5			
Millepora exaesa	16.5		25.0	
Seriatopora hystrix			50.0	
Fungia actiniformis				25.0
Acropora hyacinthus		8.5		
A. corymbosa		8.5		
A. cf. *quelchi*		8.5		
Turbinaria sp.	8.5			
Favia favus	8.5			
Tubipora musica	8.5			
Lobophyllia corymbosa	8.5			
Plesiastrea versipora	8.5			12.5
Merulina ampliata	8.5		25.0	12.5
Fungia fungites	8.5			
Pectinia lactuca	8.5			
Oulophyllia crispa	8.5		25.0	

Table 3 cont'd.

Species	Transect 2 (length 12m)	Transect 4 (length 12m)	Transect 5 (length 4m)	Transect 6 (length 8m)
Galaxia fascicularis			25.0	
Echinophyllia aspera			25.0	
Platygyra lamellina			25.0	
Echinopora horrida			25.0	
Leptoria phrygia			25.0	
Parascolymia vitiensis				12.5
Pachyseris rugosa				12.5
Acropora sp.				12.5

A. murrayensis), and encrusting to plate forms (Montipora, Echinopora lamellosa, Merulina ampliata). In the region of transect 2, Pectinia lactuca is common on coral knolls and on the reef floor; in general, in this area alcyonarian growth is more luxuriant than scleractinian growth on coral knolls.

The floor is generally sandy, and coral growth includes scattered "sprawling" Acroporas such as A. cf. syringodes and various Fungiids.

DISCUSSION

Bushy-Redbill is a large reef, which presents a variety of reef associations and zonations. In this brief study some 147 Scleractinian species, from 54 genera, (61 genera and sub-genera) were recorded, and it could be expected that rarer species and genera would be found by more intensive survey. The reef is reasonably accessible from the Queensland mainland, and Bushy Island is one of the few habitable coral cays in the central Great Barrier Reef Province. This would appear to be an excellent reef for further study of coral reef and reef-associated topics.

ACKNOWLEDGEMENTS

We wish to acknowledge the help of the staff of the Queensland Herbarium, with identification of plant specimens; A.B. Cribb, University of Queensland, with botanical advice, and M. Wilson, University of Queensland, with geological information. We also thank B. Campbell, Queensland Museum, who critically read the manuscript, and the following companions on the trip, who collected specimens and gave criticisms on the manuscript: R. Elks, W. and G. Gordon, D. Hadely, T. Nelson-Gracie, R. and J. Powell, C.J. Wallace, H. Walsh. R. Pearson (Fisheries Branch, Queensland Department of Primary Industry) and P. Beveridge (University of the South Pacific, Fiji) assisted by discussing the identification of some of the rarer coral species, and their help is gratefully acknowledged.

REFERENCES

Australia Pilot Vol IV. 1962 (5th ed.). Comprising the eastern coast of Queensland from Sandy Cape to Cape York, with the off-lying islands and reefs, including Great Barrier Reefs. Hydrographic Department, Admiralty London. 438 pp.

Hedley, C. 1925. Report of the scientific director for 1924. Trans. Roy. Geog. Soc. Australasia (Qd), Rep. Gt. Barrier Reef Comm. 1: 157-160.

Loya, Y. 1972. Community structure and species diversity of hermatypic corals at Eilat, Red Sea. Mar. Biol. 13(2): 100-123.

Maxwell, W.G.H. 1968. Atlas of the Great Barrier Reef. Elsevier. The Netherlands. 258 pp.

Steers, J.A. 1938. Detailed notes on the islands surveyed and examined by the geographical expedition to the Great Barrier Reef in 1938. Rep. Gt. Barrier Reef Comm. 4(3): 53-104.

Stephenson, W. and Wells, J.W. 1956. The corals of Low Isles, Queensland. August 1954. Univ. Qd. Pap. Dept. Zool. 1(4): 1-59, 7 plates.

Stoddart, D.R. 1969. Ecology and morphology of Recent coral reefs. Biol. Rev. 44: 433-498.

Wells, J.W. 1955. A survey of the distribution of reef coral genera in the Great Barrier Reef region. Rep. Gt. Barrier Reef Comm. 6(2): 1-9, + chart.

Wijsman-Best, Maya, 1972. Systematics and ecology of New Caledonian Faviinae (Coelenterata-Scleractinia). Bijdr. Dierk. 42(1): 3-90, 14 plates.

APPENDIX 1

Scleractinian corals and non-scleractinian hard corals recorded from Bushy-Redbill Reef

The following identifications were made (by C.W.) from literature descriptions, and wherever possible with the aid of specimens in the Queensland Museum identified by J.W. Wells (Stephenson and Wells, 1956; Wells, 1955). Many of the identifications are thus of a very tentative nature. Where specimens have been entered into the Queensland Museum collections, the registration numbers are given. Some groups, particularly the genus Acropora, have not been registered, pending further study. Species also represented in the Great Barrier Reef Committee collection are marked with an asterisk.

Other Abbreviations:

(S) sight record only
(OC) specimen collected, but not deposited in the Queensland Museum.

CLASS ANTHOZOA

SUBCLASS ZOANTHARIA

ORDER SCLERACTINIA
Suborder Astrocoeniina
Family Thamnasteriidae

Psammocora _contigua_ (Esper) G6931
_P._ cf. (_Stephanaria_) _togianensis_ Umbgrove G6927
_P._ cf. (_Plesioseris_) _haimeana_ Milne-Edwards and Haime G6925, G6934
_P._ sp.1 G6846, G6928, G6935

Pocilloporidae

Stylophora _mordax_ (Dana) G6871
_S._ _pistillata_ (Esper) G6870
Seriatopora _hystrix_ (Dana) G6874, G7220
Pocillopora _damicornis_ (Linnaeus)* G6867-8, G6872-3
_P._ _verrucosa_ (Ellis and Solander) (S)

Acroporidae

Acropora _abrotanoides_ (Lamarck).
_A._ cf. _acuminata_ Verrill
_A._ _aspera_ (Dana)
_A._ cf. _brueggemani_ (Brook)
_A._ cf. _clavigera_ (Brook)
_A._ cf. _conferta_ (Quelch)
_A._ _corymbosa_ (Lamarck)
_A._ _cuneata_ (Dana)
_A._ _decipiens_ (Brook)
_A._ _delicatula_ (Brook)
_A._ _digitifera_ (Dana)
_A._ _exilis_ (Brook)
_A._ _formosa_ (Dana)
_A._ cf. _glochiclados_ Crossland
_A._ _haimei_ Milne-Edwards and Haime
_A._ _hebes_ (Dana)
_A._ _humilis_ (Dana)*
_A._ _hyacinthus_ (Dana)
_A._ _intermedia_ (Brook)
_A._ cf. _latistella_ (Brook)
_A._ cf. _murrayensis_ Vaughan
_A._ _palifera_ (Lamarck)
_A._ _palifera_ forma _a_ (Brook)
_A._ cf. _polymorpha_ (Brook)
_A._ _pulchra_ (Brook)
_A._ cf. _quelchi_* Crossland
_A._ cf. _rosaria_ (Dana)
_A._ cf. _rotumana_ (Gardiner)
_A._ _spicifera_ (Dana)
_A._ _squamosa_ (Brook)*
_A._ cf. _syringodes_ (Brook)

A. cf. variabilis (Klunzinger)
A. sp.1 (flat plate)
A. sp.2 (fructicose)
A. sp.3 (arborescent)
A. sp.4 (arborescent)
A. sp.5 (=A. rosaria forma 1, Crossland)
A. sp.6 (plate)
Montipora danae (Milne-Edwards and Haime) G6875, G6877, G6881
M. divaricata Brueggeman G6917
M. erythraea von Marenzeller G6913-6
M. foliosa (Pallas) G6921
M. foveolata (Dana) G6920
M. verrucosa (Lamarck) G6879-81
M. sp.1 G6923
M. sp.2 G6922
M. sp.3 G6884
M. sp.4 G6885
M. sp.5 G6924
M. sp.6 G6883
Astreopora myriophthalma (Lamarck) G6763, G6951
A. sp.1 G6946, G6949
A. sp.2 G6896

Suborder Fungiina
Super Family Agariciicae
Agariciidae

"Agariciella" ponderosa (Gardiner) G7219
Pavona cf. clavus (Dana) G6926
P. cf. decussata (Dana) G6843
P. frondifera Lamarck G6841, G6844, G6932
P. (Pseudocolumnastrea) pollicata Wells G6842
Pachyseris rugosa (Lamarck) G6838
P. speciosa (Dana) G6839
Leptoseris ?mycetoseroides Wells G6930

Siderastreidae

Anomastraea (Pseudosiderastrea) tayamai (Yabe and Sugiyama) G7230
Coscinaraea columna (Dana) G6840, G6845

Super Family Fungiicae
Fungiidae

Fungia (Ctenactis) echinata (Pallas) (OC)
F. (Pleuractis) scutaria (Lamarck) G6779
F. (Heliofungia) actiniformis Quoy and Gaimard (OC)
F. (Fungia) fungites (Linnaeus) G6775, G6777-8
Herpolitha limax (Esper) G6772, G6774
Polyphyllia talpina (Lamarck) G6776
Parahalomitra robusta (Quelch) G6771, G6773
Podobacia crustacea (Pallas) G6933

Super Family Poriticae
Poritidae

Goniopora tenuidens (Quelch) G6816, G6939
G. lobata Milne-Edwards and Haime G6817, G6942
Porites andrewsi Vaughan G6832-5
P. annae Crossland G6823-6
P. lobata Dana G6827-8
P. lichen Dana G6831, G6938
P. lutea Milne-Edwards and Haime* G6829-30, G6936-7
P. sp.1 (branching) G6818-22
P. sp.2 (branching) G6837, G6940-1
Alveopora mortenseni Crossland G6929
A. sp.1 G6836

Suborder Faviina
Super Family Faviicae
Faviidae
Subfamily Faviinae

Caulastrea furcata Dana G6897-9, G7040
Favia favus (Forskaal) G7185-6
F. pallida (Dana) G7200
F. speciosa (Dana) G7184, G7202
F. stelligera (Dana) G7183, G7201
F. cf. matthai
F. cf. valenciennesi G7188
Favites abdita (Ellis and Solander) G7205-8
F. flexuosa (Dana) G7197, G7209, G7221
F. virens (Dana) G7210-1
Oulophyllia crispa (Lamarck) G6894-5, G7199
Goniastrea pectinata* (Ehrenberg) G6853, G6855, G6904
Goniastrea australensis (Milne-Edwards and Haime) G6903, G6905, G6907, G6912, G7190-1
G. retiformis (Lamarck) G6851, G6955
Platygyra sinensis (Milne-Edwards and Haime)* G6856-7
P. daedalea Ellis and Solander G6852, G7213
P. lamellina (Ehrenberg) G6854
Leptoria phrygia (Ellis and Solander)
Hydnophora rigida (Dana) G6762, G6765
H. exesa (Pallas) G6893

Subfamily Montastreinae

Montastrea curta (Dana) G6850, G6901-2, G6911
Plesiastrea versipora (Lamarck) G7187
Leptastrea purpurea (Dana) G6908-10, G7187, G7214-7
L. transversa Klunzinger G7212
Cyphastrea japonica Yabe and Sugiyama G6886, G6890
C. serailia (Forskaal) G6887-8
Echinopora gemmacea (Lamarck) G6889
E. horrida Dana G6769
E. lamellosa (Esper) G6766-8, G6891-2

Oculinidae
Galaxeinae

<u>Galaxia</u> <u>fascicularis</u> (Linnaeus) G7099
<u>Acrhelia</u> <u>horrescens</u> (Dana) (OC)

Merulinidae

<u>Merulina</u> <u>ampliata</u> (Ellis and Solander) G6866
<u>Clavarina</u> <u>scabricula</u> (Dana) G6761

Mussidae

<u>Acanthastrea</u> <u>echinata</u> (Dana) G6900
<u>Lobophyllia</u> <u>corymbosa</u> (Forskaal) G7101, G7105
<u>L</u>. <u>costata</u> (Dana) G7100, G7103-4, G7107, G7109
<u>L</u>. <u>hemprichii</u> (Ehrenberg) G7102
<u>L</u>. (<u>Palauphyllia</u>) <u>hataii</u> Yabe, Sugiyama and Eguchi G7106
<u>Symphyllia</u> <u>nobilis</u> (Dana) G6764
<u>Parascolymia</u> <u>vitiensis</u> (Brueggeman) G7039, G7041-2
<u>Cynarina</u> <u>lacrymalis</u> (Milne-Edwards and Haime) G7043

Pectiniidae

<u>Echinophyllia</u> <u>aspera</u> Ellis and Solander G6859-60, G6944
<u>Mycedium</u> <u>tubifex</u> (Dana) G6862-63, G6865
<u>Pectinia</u> <u>lactuca</u> (Pallas) G6861
<u>Oxypora</u> <u>lacera</u> (Verrill) (S)

Suborder Caryophylliina
Super Family Caryophylliicae
Caryophylliidae
Eusmiliinae

<u>Euphyllia</u> <u>glabrescens</u> (Chamisso and Eysenhardt) G6876, G7145
<u>Catalophyllia</u> <u>plicata</u> (Milne-Edwards and Haime) G6895
<u>Physogyra</u> <u>lichtensteini</u> (Milne-Edwards and Haime) (S)
<u>Plerogyra</u> sp. (OC)

Suborder Dendrophylliina
Dendrophylliidae

<u>Dendrophyllia</u> <u>nigrescens</u> (Dana) G6869
<u>Tubastrea</u> sp.
<u>Turbinaria</u> <u>peltata</u> (Esper) G6849, G6954
<u>T</u>. cf. <u>lichenoides</u> Bernard G6848
<u>T</u>. sp.1 G6847, G6945
<u>T</u>. sp.2 G6952
<u>T</u>. sp.3 G6948
<u>T</u>. sp.4 G6858

<u>Non-Scleractinian corals</u>

SUBCLASS OCTOCORALLIA

STOLONIFERA
Tubiporidae

Tubipora musica (Linnaeus)*

CLASS HYDROZOA

MILLEPORINA
Milleporidae

Millepora exaesa Forskaal G7218, G7222
M. tenera Boschma G7223-4

APPENDIX 2

Vascular plant flora of Bushy and Redbill Islands

Bushy Island:

PANDANACEAE

Pandanus sp.

GRAMINEAE

Sporobolus virginicus (L.) Kunth
Thuarea involuta (Forst.) R. & S.

PALMAE

Cocos sp.

CHENOPODIACEAE

Salsola kali L.

CASUARINACEAE

Casuarina equisetifolia L.

NYCTAGINACEAE

Pisonia grandis R. Br.

AIZOACEAE

Sesuvium portulacastrum (L.) L.

LAURACEAE

Cassytha filiformis L.

TILIACEAE

Triumfetta procumbens Forst. f.

LEGUMINOSAE

Sophora tomentosa L.

MALVACEAE

Abutilon albescens Miq.

CONVOLVULACEAE

Ipomoea pes-caprae (L.) R. Br.

BORAGINACEAE

Tournefortia argentea L.f.
Cordia subcordata Lam.

MYOPORACEAE

Myoporum acuminatum R. Br.

VERBENACEAE

Vitex trifolia L.

GOODENIACEAE

Scaevola taccada (Gaertn.) Roxb.

COMPOSITAE

Tridax procumbens L.

Redbill Island:

GRAMINEAE

Thuarea involuta (Forst.) R. & S.

MORACEAE

Ficus opposita Miq.

AIZOACEAE

Sesuvium portulacastrum (L.) L.

Plate 1: Air photograph of Bushy-Redbill Reef. Crown copyright reserved; reproduced from material supplied by the Department of Minerals and Energy, Canberra.

Plate 2: Reef flat between Redbill Island (foreground) and Bushy Island, showing borken algal banks.

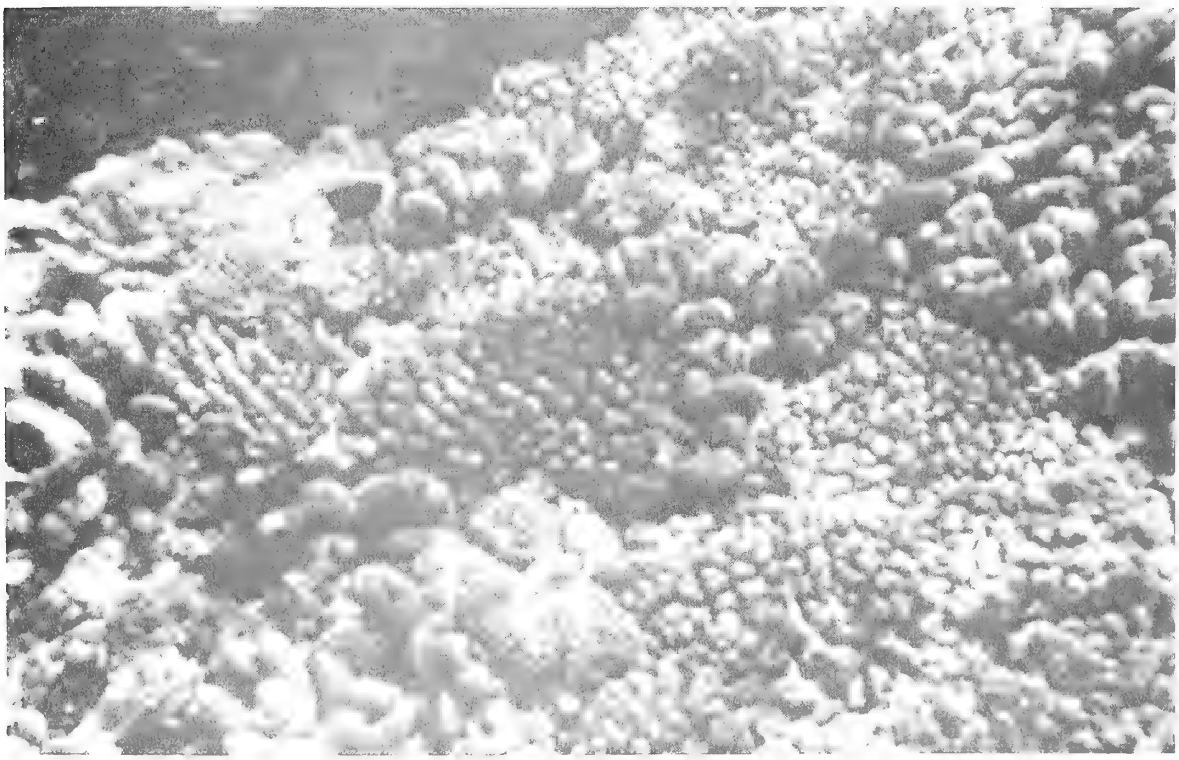


Plate 3: Reef crest in the vicinity of transect 4 (exposed side of reef).

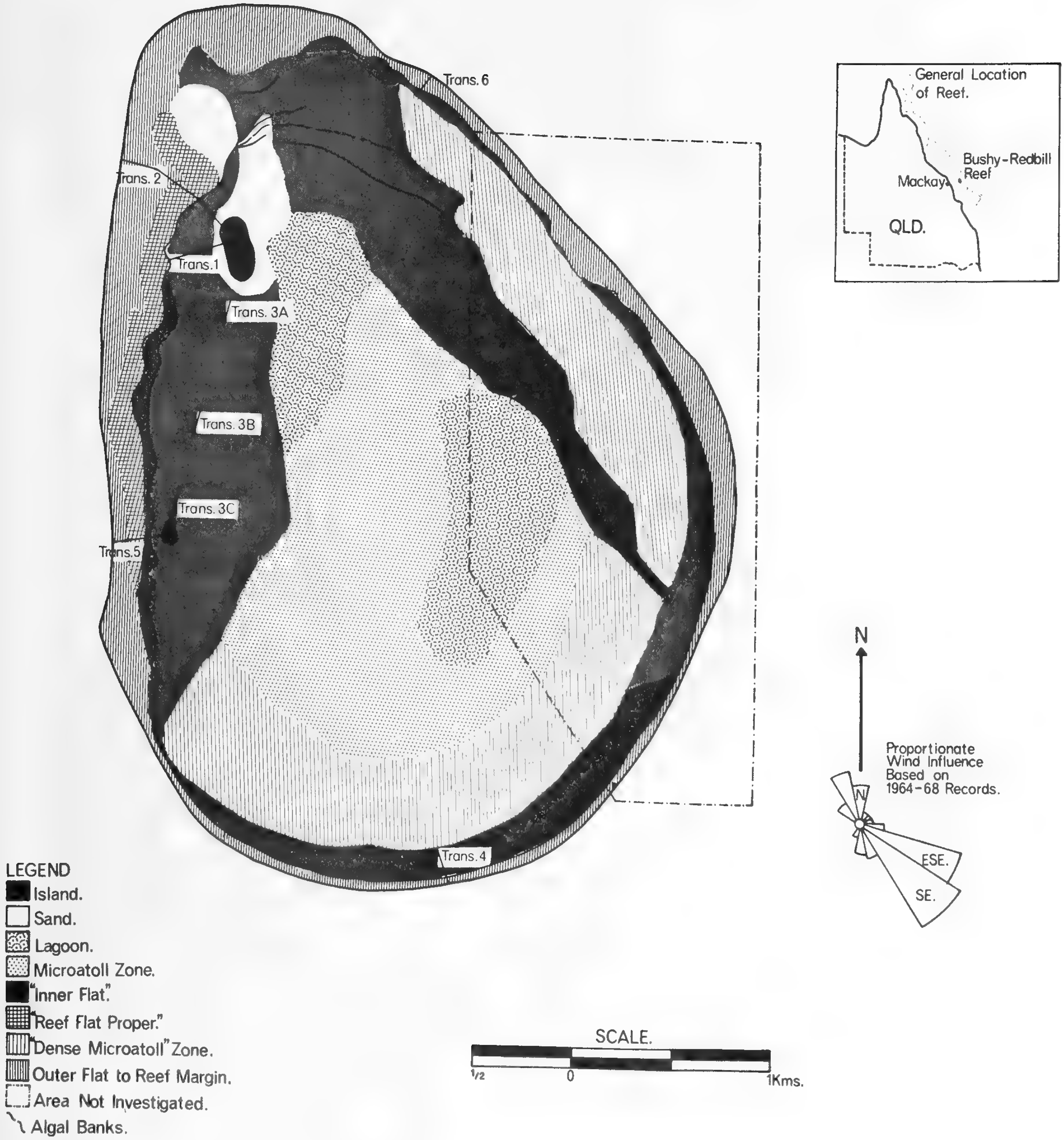


Fig. 1: Diagrammatic representation of general zonation of Bushy-Redbill Reef, with position of transect lines indicated. Insets indicate prevailing winds and relative position of the reef with reference to the Queensland coast.

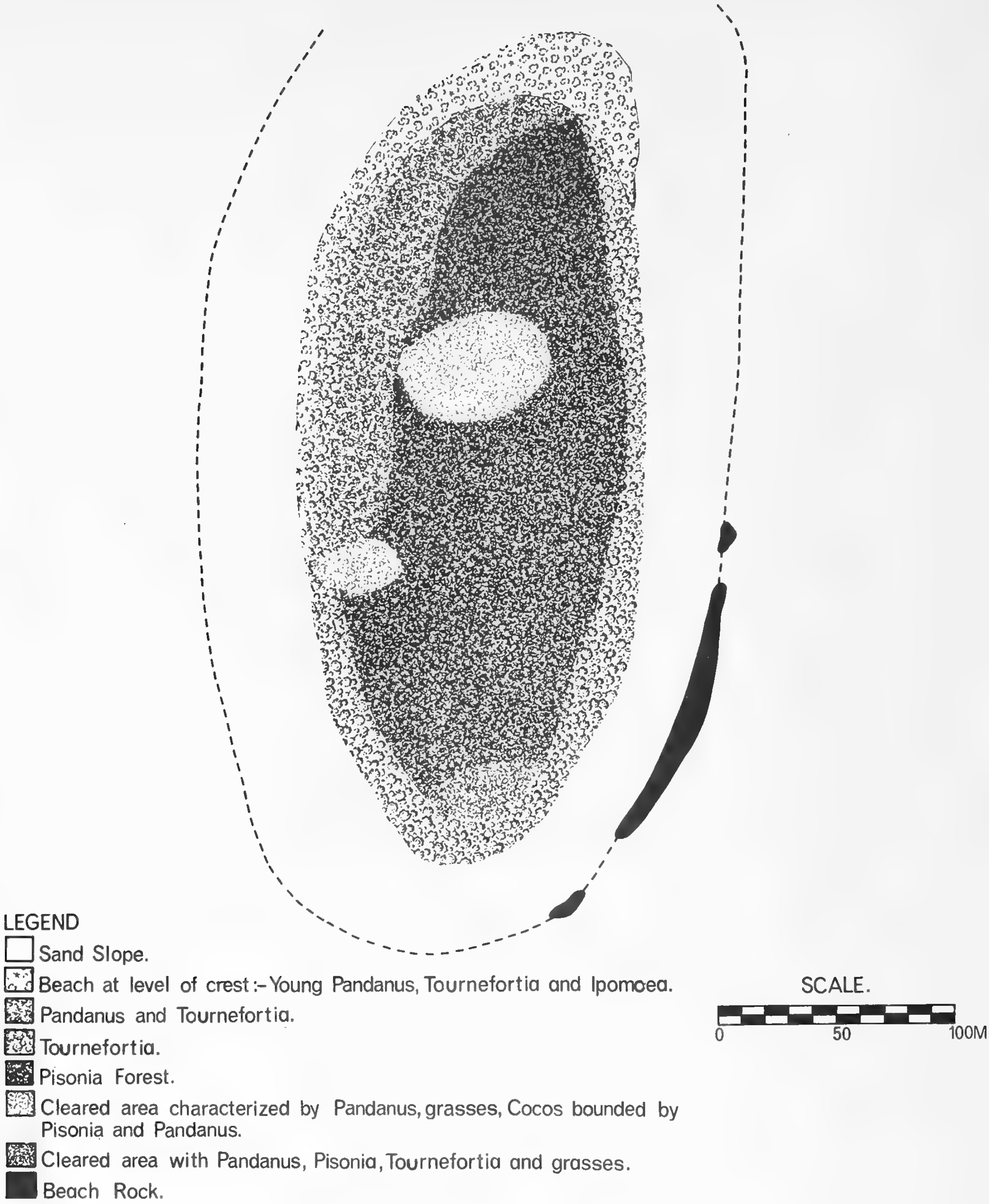
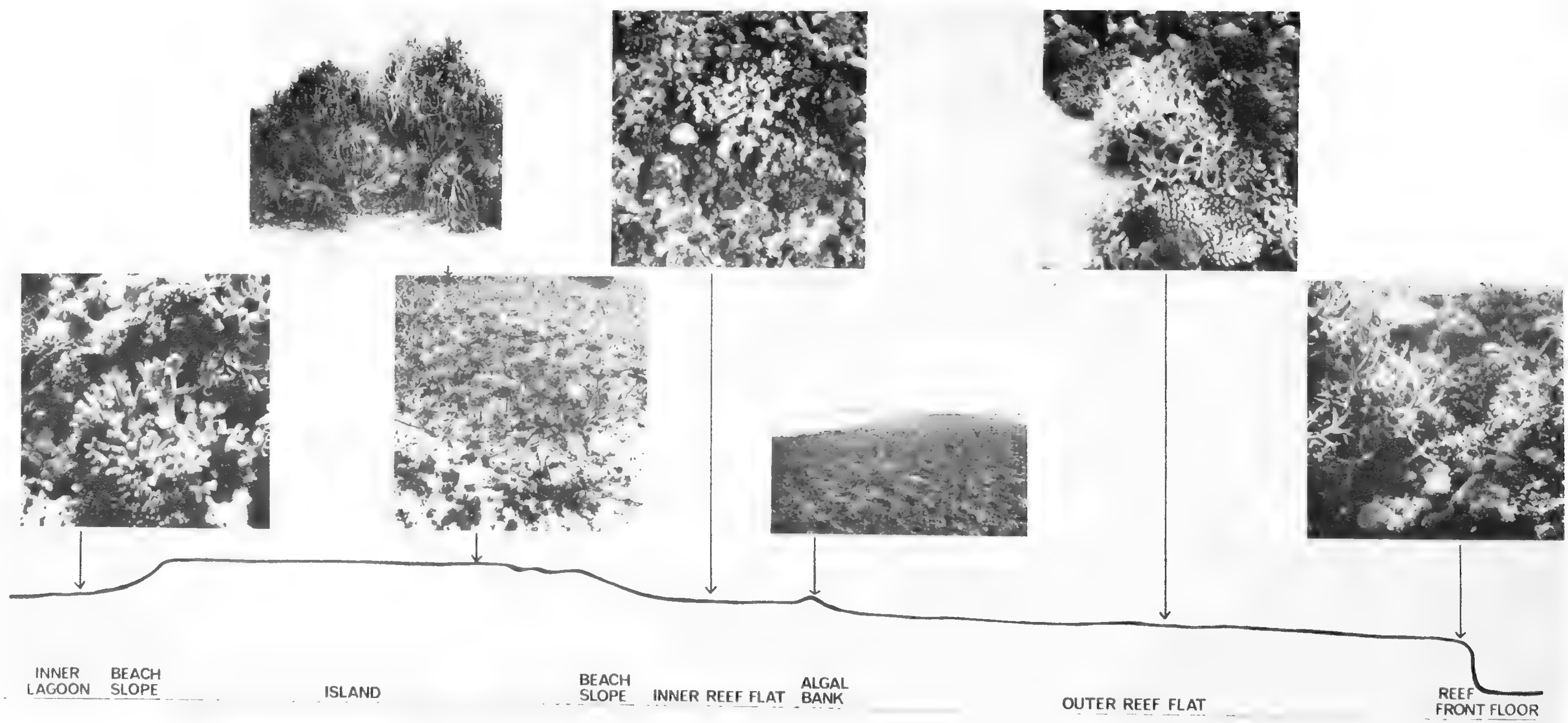


Fig. 2: Zonation of the dominant vegetation of Bushy Island. Position of beach rock also noted.

Fig. 3: Schematic profile of Bushy Island and adjacent reef and lagoon in the vicinity of transect 2. Selected photographs typifying reef zones and vegetation have been included.



ATOLL RESEARCH BULLETIN

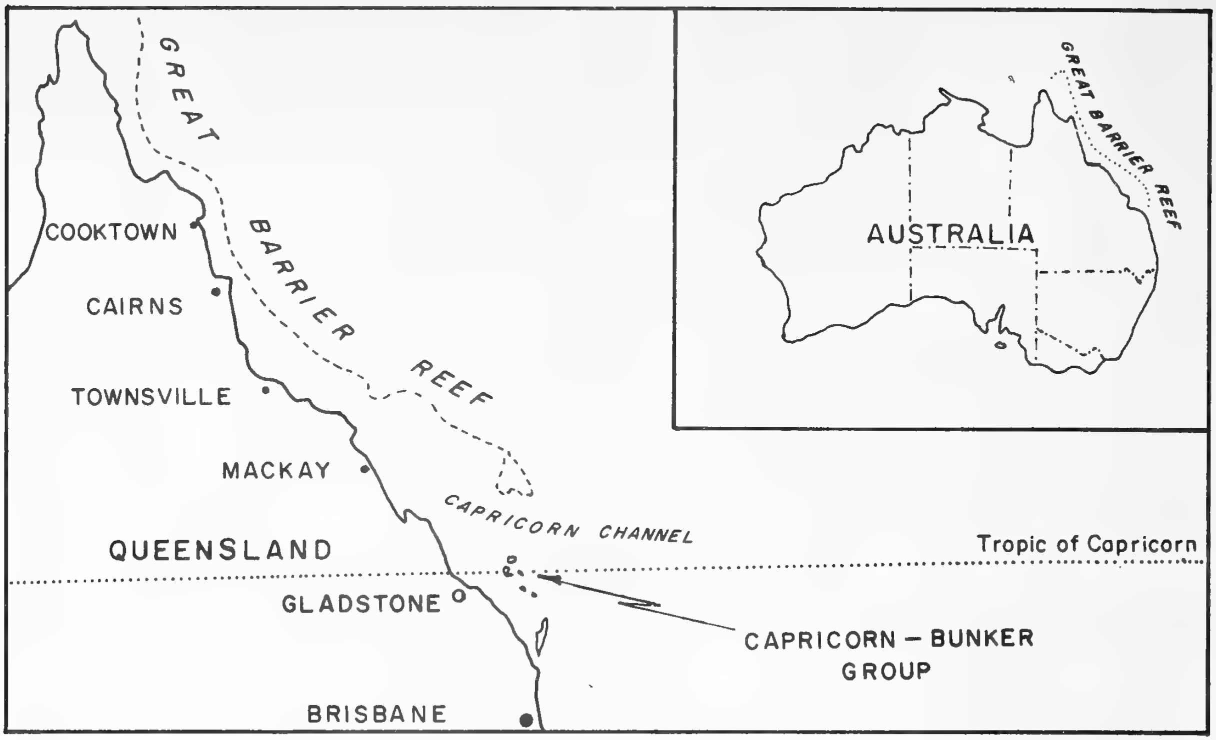
NO. 195.

CORAL CAYS OF THE CAPRICORN AND BUNKER GROUPS, GREAT BARRIER REEF PROVINCE, AUSTRALIA

by P. G. Flood

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977



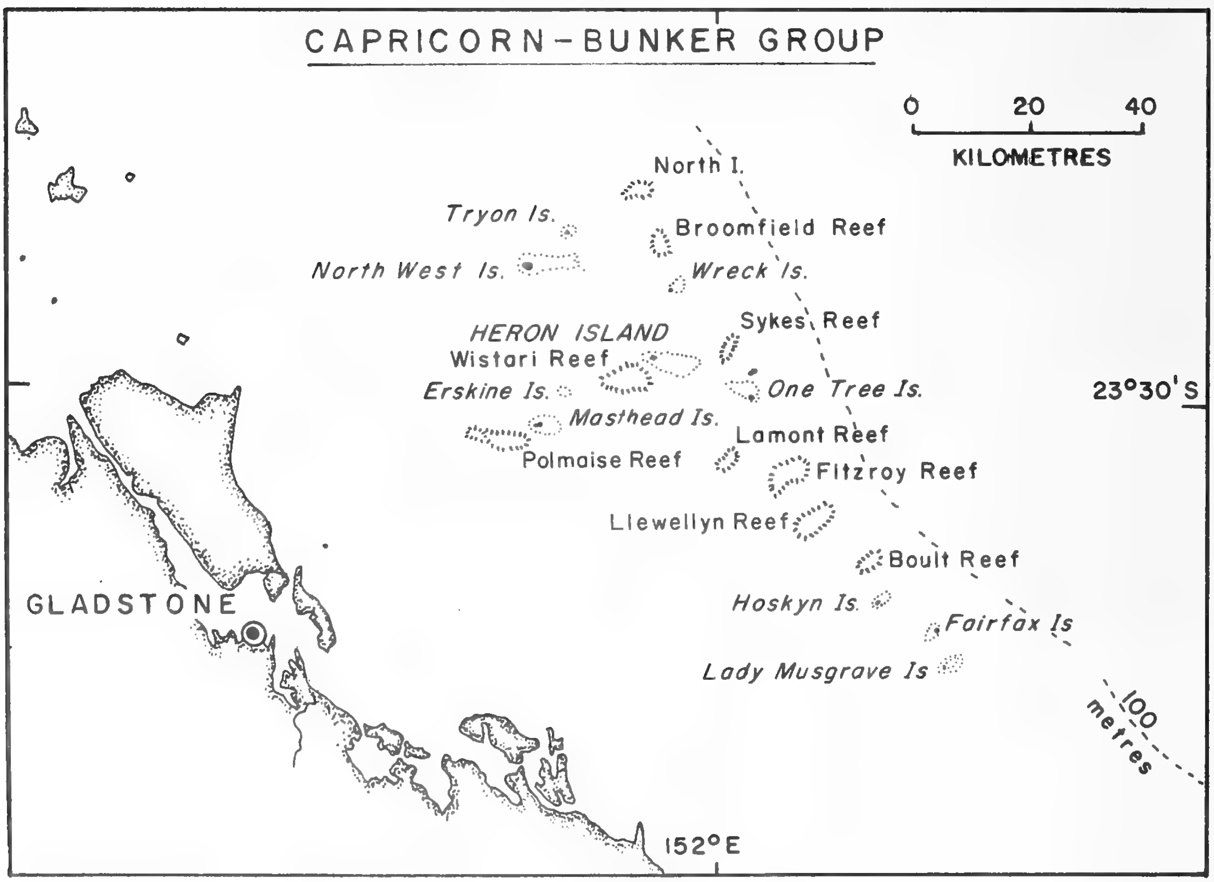


Fig. 1. Location of the Capricorn and Bunker Groups.

CORAL CAYS OF THE CAPRICORN AND BUNKER GROUPS, GREAT BARRIER REEF PROVINCE, AUSTRALIA

by P.G. Flood [1]

Introduction

The islands and reefs of the Capricorn and Bunker Groups are situated astride the Tropic of Capricorn at the southern end of the Great Barrier Reef Province and approximately 80 kilometres east of Gladstone which is situated on the central coast of Queensland (Fig. 1).

The Capricorn Group of islands consists of nine coral cays: North Island, Tryon Island, North West Island, Wilson Island, Wreck Island, Masthead Island, Heron Island, and One Tree Island. A tourist Resort and Marine Scientific Research Station have been established on Heron Island. A manned lighthouse operates at North Island and the Australian Museum conducts a field research station on One Tree Island. The Bunker Group consists of five coral cays: Lady Musgrave Island, Fairfax Islands (West and East), and Hoskyn Islands (West and East).

Morphological changes occurring between 1936 and 1973 are evident when comparing previous plans of these coral cays (Steers, 1938) with recent vertical aerial photographs. Changes are catagorised into two groups; those related to natural phenomena and secondly, those caused by human interference.

Previous work

The earliest scientific description of the Capricorn and Bunker Groups is that of Jukes (1847) who visited the area in 1843 on the voyage of H.M.S. *Fly*. Saville-Kent (1893) and Agassiz (1898) make brief references to the Groups. Steers (1937, 1938) provided the first detailed descriptions and sketches of most islands of the Groups.

---

[1] Department of Geology and Mineralogy, University of Queensland, Brisbane, Australia.

(Manuscript received July 1974 -- Eds.)

The regional location, bathymetry, and physiography of this area has been discussed by various authors (Maxwell, 1968; Maiklem, 1968, 1970; Maxwell and Maiklem, 1964) and the island vegetation has been mentioned by several workers (MacGillivray and Rodway, 1931; Fosberg and Thorne, 1961; Gillham,1963; Cribb, 1965, 1969; Domm, 1971).

Steers (1938) and Domm (1971) provide an introduction to the Groups and both papers should be read in conjunction with this article.

Reefs with coral cays

Four distinct reef types (Maxwell, 1968) occur within the Capricorn and Bunker Groups (Figs. 2, 3, 4 and 5):

1. Platform Reefs:- Tyron, Wreck, North, Wilson, and Erskine Reefs.
2. Lagoonal Platform Reefs:- Heron, and One Tree Reefs.
3. Elongate Platform Reefs:- North West, and Masthead Reefs.
4. Closed Ring Reefs:- Lady Musgrave, Fairfax, and Hoskyn Reefs.

The reader is referred to Maiklem (1968) and Maxwell (1968) for detailed discussions concerning the zonation of individual reef types.

The coral cays belong to two distinct types (Fairbridge, 1950):

1. Vegetated sand cays:- North West, Heron, Masthead, Erskine, Wilson, Wreck, Tryon, North, Fairfax (West), and Hoskyn (West).
2. Shingle cays:- One Tree, Lady Musgrave, Fairfax (East), and Hoskyn (East).

The sand cays are all located to the lee of their reef flat, whereas the shingle cays, with the exception of Lady Musgrave, are located on the windward side.

The following brief descriptions are provided to assist interpretation of the vertical aerial photographs (Plates 1-9) and to allow comparisons to be drawn between present cay morphology and that illustrated in sketches made by the Geographical Expedition to the Great Barrier Reef in 1936 (Figs. 6 and 7).

Capricorn Group

Heron Island (Plate 1)

A sandy beach, 15-30 metres wide at low tide, surrounds the cay. Exposed beachrock occurs on the southern, northern, and eastern beaches. Vegetation consists of a central zone of *Pisonia grandis* and an outer zone of *Casuarina equisetifolia, Scaevola taccada,* and *Tournefortia argentea*. *Pandanus tectorius* occurs over the centre of the cay. A Tourist Resort and Research Station have been developed on the western end of the cay.

Changes occurring since 1936 are related to the natural elements and to human interference. Sand erosion on the northern and eastern beaches has exposed new occurrences of beachrock. The construction of a retaining wall and a boat harbour have drastically altered the western end of the cay.

North West Island (Plate 2)

This is the largest sand cay of the Group. A sandy beach surrounds the cay and beachrock is only exposed at the eastern end. Vegetation is similar to that occurring on Heron Island.

The eastern area of exposed beachrock is smaller now than in 1936 and the southwestern outcrop is no longer visible.

Masthead Island (Plate 3)

Beachrock is well developed along the southern beach and an occurrence of older beachrock is situated some distance from the beach on the northwestern corner of the cay. Vegetation is similar to that occurring on Heron Island. Prickly Pear, introduced from the Mainland, is now well established over the entire cay.

Considerably more beachrock is now exposed on the southern beach and a spit has formed on the northwestern corner. The shingle and sand spit which was prominent in 1936 has disappeared.

One Tree Island (Plate 4)

This is a shingle cay. Vegetation consists of scattered *Tournefortia argentea* and *Scaevola taccada* with several small groves of *Pisonia grandis*. A small pond of brackish water is situated near the centre of the cay. A temporary Field Research Station conducted by the Australian Museum is located towards the northeastern corner of the cay.

The straight alignment of the western beach in 1936 has been altered by the addition of a small spit near the northwestern end of the beach. The northwestern corner of the cay has extended towards the lagoon.

Tryon Island (Plate 5)

Beachrock occurs along the northwestern and southeastern beaches. The cay is covered with dense vegetation in the same zonations as on the larger sand cays.

The areas of outcropping beachrock have altered considerably since 1936. No exposures can be seen on the northeastern beach, whereas the exposures on the northwestern and southwestern beaches have increased in area.

Wreck Island (Plate 5)

Beachrock is well developed along the southern beach. Vegetation is similar to that on Tryon Island except that the *Pisonia grandis* forest is less well developed.

No apparent changes have occurred since 1936.

North Island (Plate 6)

This is the smallest cay of the Group. A manned lighthouse operates on this island.

Steers (1938) does not describe this island.

Wilson Island (Plate 6)

This island is not a true sand cay because of the quantity of coarse coral shingle present in the sediments. Beachrock is well-developed along the southeastern beach. *Pandanus tectorius* is the dominant vegetation with *Casuarina equisetifolia* restricted to the western side of the cay.

Significant changes have occurred since 1936. Considerable quantities of sand have moved, exposing beachrock on the northern beach and covering formerly exposed beachrock on the southern beach. The sandy beach on the western side has increased in area.

Erskine Island

Beachrock is well developed on the western and northwestern beaches. The vegetation differs from that present on the other cays in that *Pandanus tectorius* and *Casuarina equisetifolia* are absent, and the main vegetation consists of *Tournefortia argentea, Scaevola taccada,* and stunted *Pisonia grandis*.

The cay has increased in size since 1936 and sand now covers most of the formerly exposed beachrock.

Bunker Group

Lady Musgrave Island (Plate 7)

This island is the only shingle cay situated on the leeward reef flat. Beachrock is exposed along the northeastern and eastern beaches and an outcrop of lithified coral conglomerate, similar to that forming the core of the cay, occurs near the southeastern corner. Vegetation consists of *Pisonia grandis, Tournefortia argentea, Casuarina equisetifolia,* and *Pandanus tectorius*. The vegetation is less dense than that of the larger sand cays of the Capricorn Group. A small pond of brackish water is located towards the southern end of the cay.

The shapes of the southeastern and eastern beaches have altered since 1936. Erosion has exposed a larger area of beachrock on the southern beach and the eroded sand has been deposited on the eastern beach partly obscuring the beachrock exposed in 1936 and forming a well-defined beach on the northeastern corner of the cay.

Fairfax Islands (Plate 8)

The eastern cay is composed of shingle and the western of sand and shingle. Interference with the vegetation of the eastern cay occurred as a result of phosphate mining and secondly during the period when the Australian Military Forces used the area as a bombing target. The cay is no longer used for either purposes. Vegetation is dominated by *Pisonia grandis* which is restricted to the centre of the island. Two brackish pools are located towards the eastern end of the island.

The western cay features an elongated sand spit that supports vegetation on its western extremity. Vegetation is similar to that occurring on the larger sand cays of the Capricorn Group. A tin shed, erected by the Australian Navy when the eastern cay was used for bombing practice, is located in the centre of the island. This shed has been occupied for the past three years by Julie Booth who is studying the behaviour of marine turtles.

Steers (1937) mentions the islands. However, he did not provide any sketch of the cays.

Hoskyn Islands (Plate 9)

The eastern cay is composed of shingle and supports vegetation similar to, although less well-developed than, that of Lady Musgrave Island. The western cay is composed of sand and its vegetation is similar to that of the larger sand cays Capricorn Group.

Both cays have increased in size since 1936.

Influences causing morphological changes, 1936-1973

Most cays have changed morphologically as a result of continued erosion of sand on the eastern, southern, and southeastern beaches and subsequent deposition of sand on the western and northwestern beaches. The Southeast Trade Wind which blows for approximately nine months of the year causes this natural pattern to be common within this region (Flood, in press) and accounts for the nett westerly migration of sand on each cay.

Human interference is responsible for significant changes at Heron Island (Plate 10). A concrete retaining wall constructed in the early 1960's on the northwestern corner of the island is responsible for erosion of the western beach (Fig. 8). The wall alignment reflects and refracts onto the western beach those waves approaching the island from a northwesterly and northeasterly direction and considerably increases the erosive energy of waves in that area.

The erosion problem was increased in 1967 by the dredging of a boat harbour into the reef flat to provide access to the tourist resort (Plate 10, fig. 2). Even before cyclone "Emily" (April, 1972)

the retaining walls of the harbour were breached in several places, allowing sand from the western end of the island to move into the harbour and to the deeper water beyond (Plate 10, fig. 3). The boat harbour was redredged in late 1972. Approximately 20,000 cubic metres of sand were placed adjacent to the concrete retaining wall on the northwestern corner of the island in an attempt to lessen its erosive influence (Plate 10, fig. 4). The sand is migrating westward by longshore drift under the influence of the Southeast Trade.

Acknowledgements

The author gratefully acknowledges the use of research facilities at the Department of Geology and Mineralogy, University of Queensland, and at the Heron Island Research Station. I am particularly grateful to Dr. G.R. Orme who organised the fieldtrips and aerial reconnaissance of most cays of the Capricorn and Bunker Groups in 1972. The Co-ordinator-General's Department, Queensland is thanked for reproductions used in Plates 2 and 3. The officers of the No. 2 Sqdn. Royal Australian Air Force, Amberley generously supplied the aerial photographs of the coral cays illustrated in Plates 1 and 4 to 9 inclusive.

References

Agassiz, A. 1899. A visit to the Great Barrier Reef of Australia in the steamer "Croyden" during April and May, 1896. *Bull. Harvard Mus. Comp. Zoology* 26: 1-203.

Cribb, A.B. 1965. The marine and terrestrial vegetation of Wilson Island, Great Barrier Reef. *Proc. R. Soc. Qd.* 77: 53-65.

Cribb, A.B. 1969. The vegetation of North West Island. *Qd Nat.* 19: 85-93.

Domm, S.D. 1971. The Uninhabited Cays of the Capricorn Group, Great Barrier Reef, Australia. *Atoll Res. Bull.* 142: 1-27

Fairbridge, R.W. 1950. Recent and Pleistocene coral reefs of Australia. *J. Geol.* 58: 330-401.

Flood, P.G. in press. Sand movement on Heron Island - a vegetated sand cay, Great Barrier Reef Province, Australia. *Proc. 2nd Intern. Symp. Corals and Coral Reefs,* 1973.

Fosberg, F.R. and Thorne, R.F. 1961. Vascular plants of Heron Island, pp. 5-13 in Fosberg *et al.,* Heron Island, Capricorn Group, Australia. *Atoll Res. Bull.* 82: 1-16.

Gillham, M.E. 1963. Coral cay vegetation, Heron Island, Great Barrier Reef. *Proc. R. Soc. Qd* 73: 79-92.

Jukes, J.B. 1847. *Narrative of the Surveying Voyage of H.M.S. Fly.* Boone, London. 1: 424 pp.

MacGillivray, W.D.K. and Rodway, F.A. 1931. Plants on islands of the Bunker and Capricorn Groups. *Rep. Gt Barrier Reef Comm.* 3(7): 58-63.

Maiklem, W.R. 1968. The Capricorn Reef Complex, Great Barrier Reef, Australia. *J. sedim. Petrol.* 38(3): 785-798.

Maiklem, W.R. 1970. Carbonate Sediments in the Capricorn Reef Complex, Great Barrier Reef, Australia. *J. sedim. Petrol.* 40(1): 55-80.

Maxwell, W.G.H. 1968. *Atlas of the Great Barrier Reef.* Elsevier, Amsterdam. 258 pp.

Maxwell, W.G.H. and Maiklem, W.R. 1964. Lithofacies analysis, southern part of the Great Barrier Reef. *Pap. Dep. Geol. Univ. Qd* 5(11): 1-21.

Saville-Kent, W. 1893. *The Great Barrier Reef of Australia.* Allen, London. 387 pp.

Steers, J.A. 1937. The coral islands and associated features of the Great Barrier Reefs. *Geogrl J.* 89: 1-28, 119-146.

___________ 1938. Detailed notes on the islands surveyed and examined by the Geographical Expedition to the Great Barrier Reef in 1936. *Rep. Gt Barrier Reef Comm.* 4(3): 51-96.

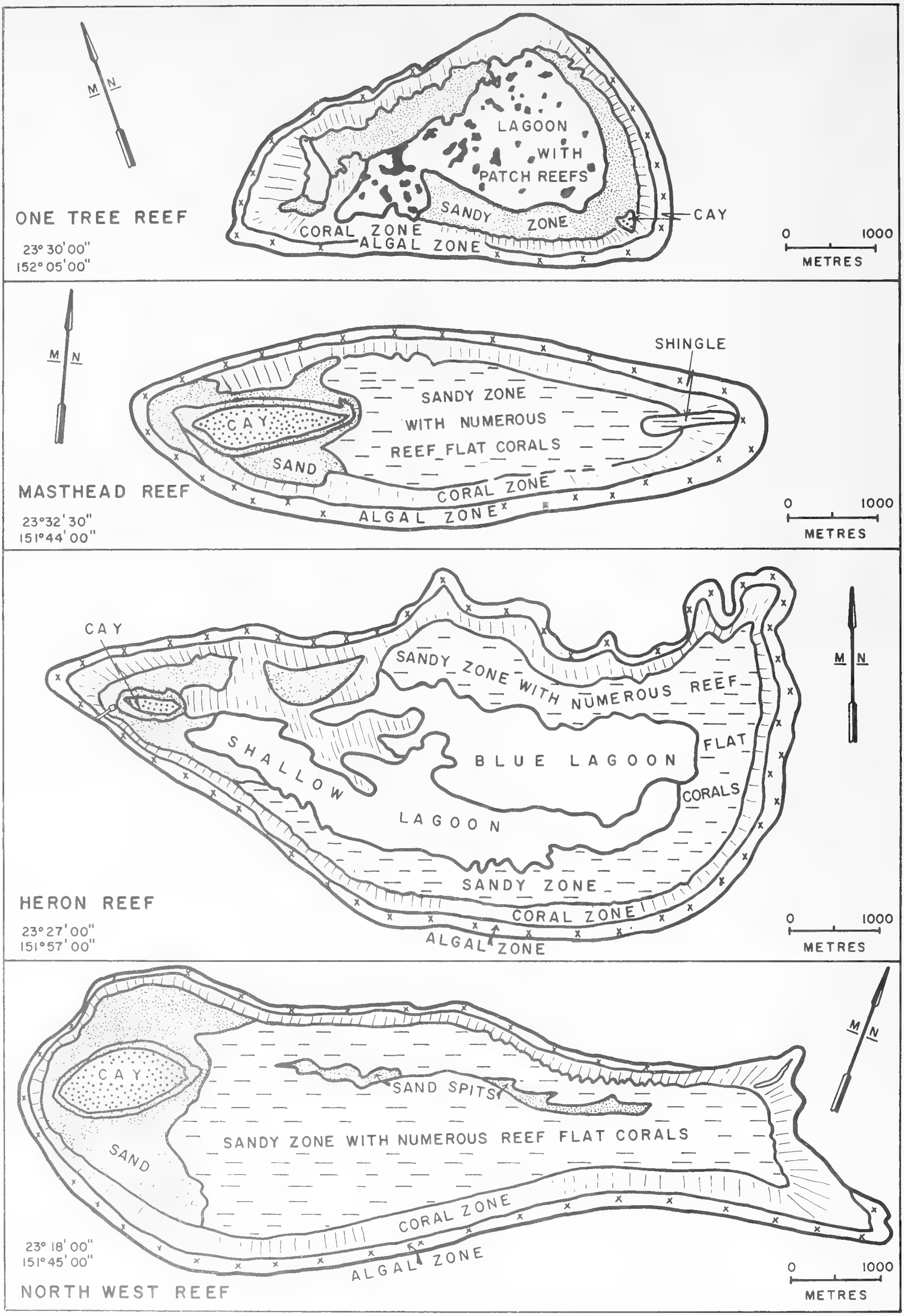


Fig. 2. Reef zonation: One Tree, Masthead, Heron, and North West Reefs.

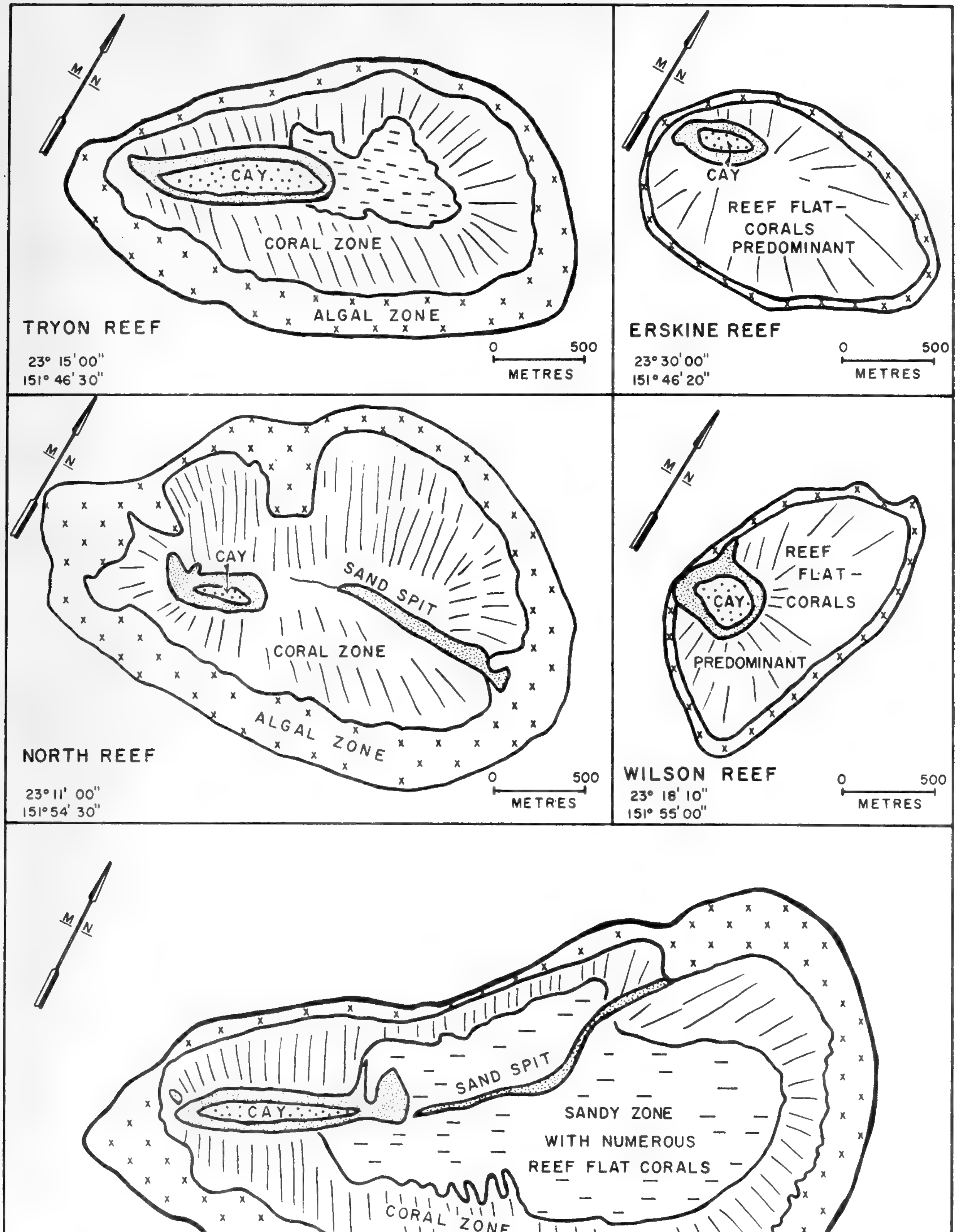


Fig. 3. Reef zonation: Tryon, Erskine, North, Wilson, and Wreck Reefs.

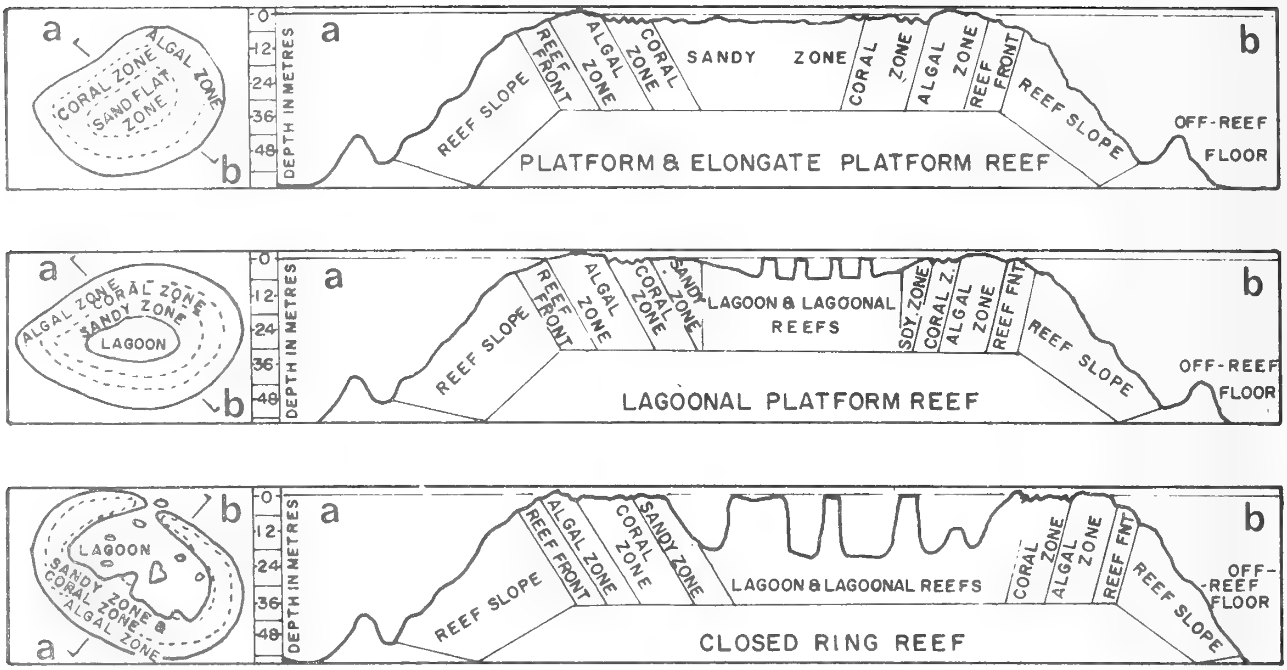


Fig. 4. Physiographic zonation of the reef types of the Capricorn and Bunker Groups (modified from Maxwell, 1968, p.106).

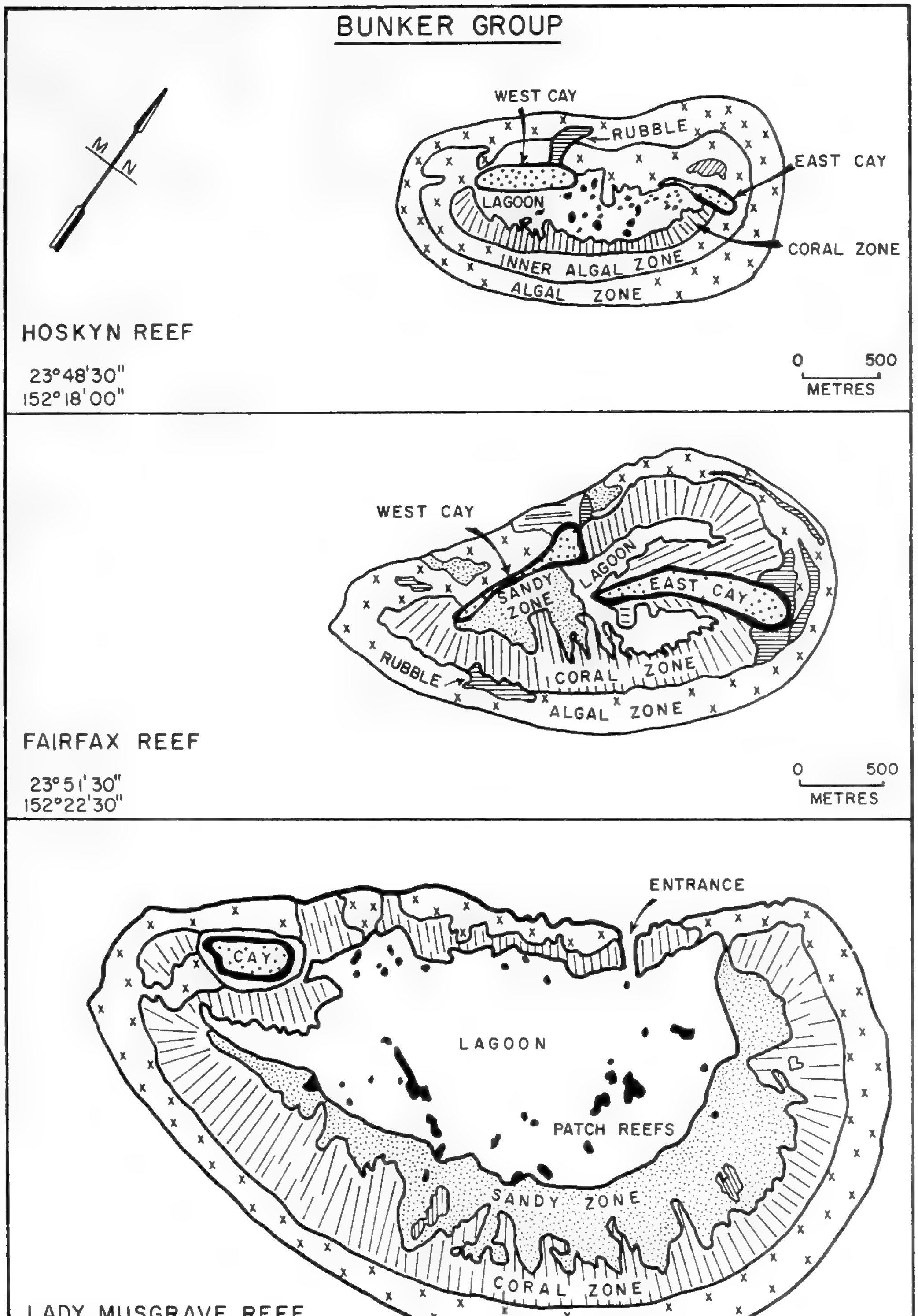


Fig. 5. Reef zonation; Hoskyn, Fairfax, and Lady Musgrave Reefs.

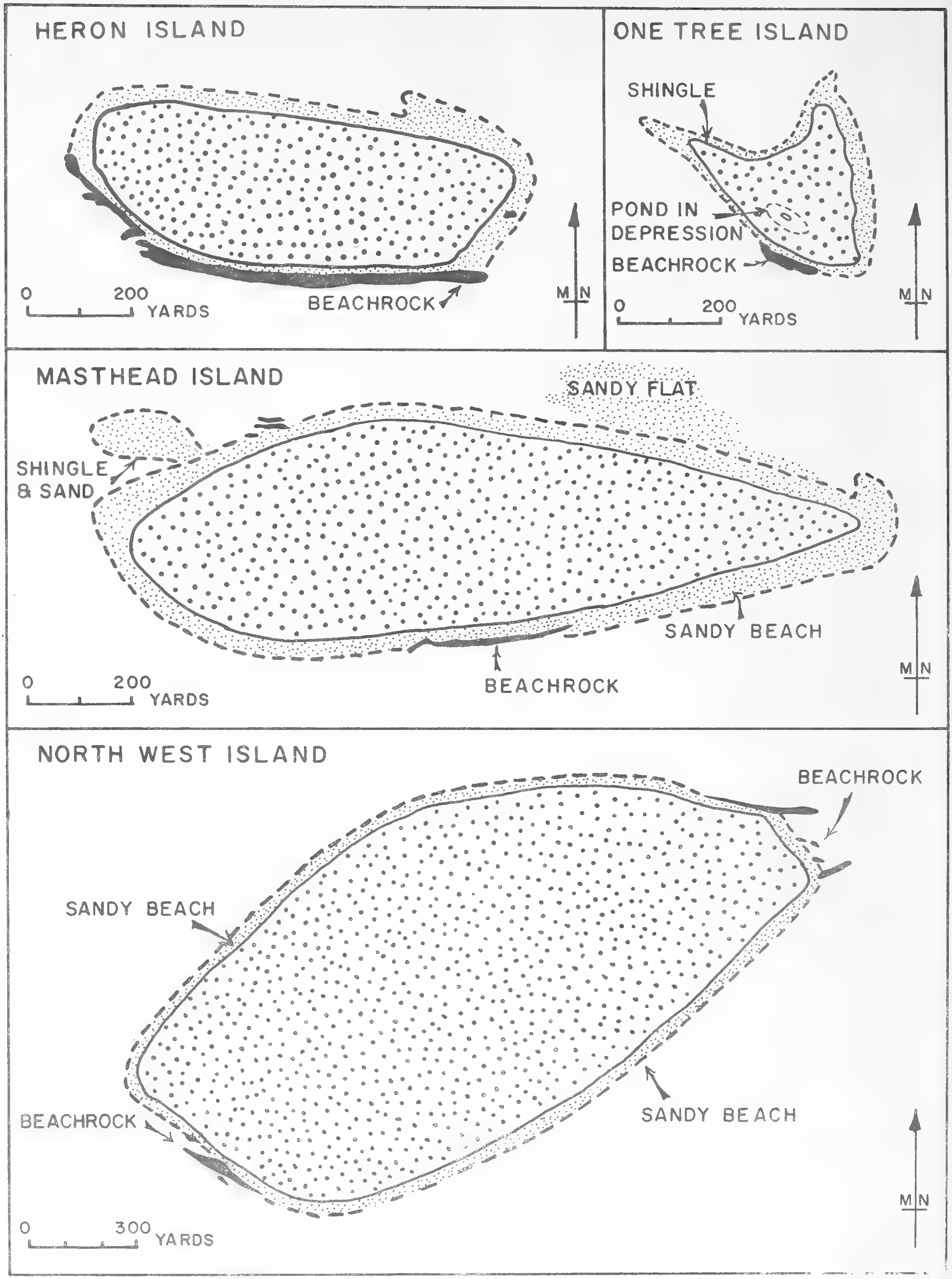


Fig. 6. Shape of coral cays in 1936 (after Steers, 1938): Heron, One Tree, Masthead, and North West Islands.

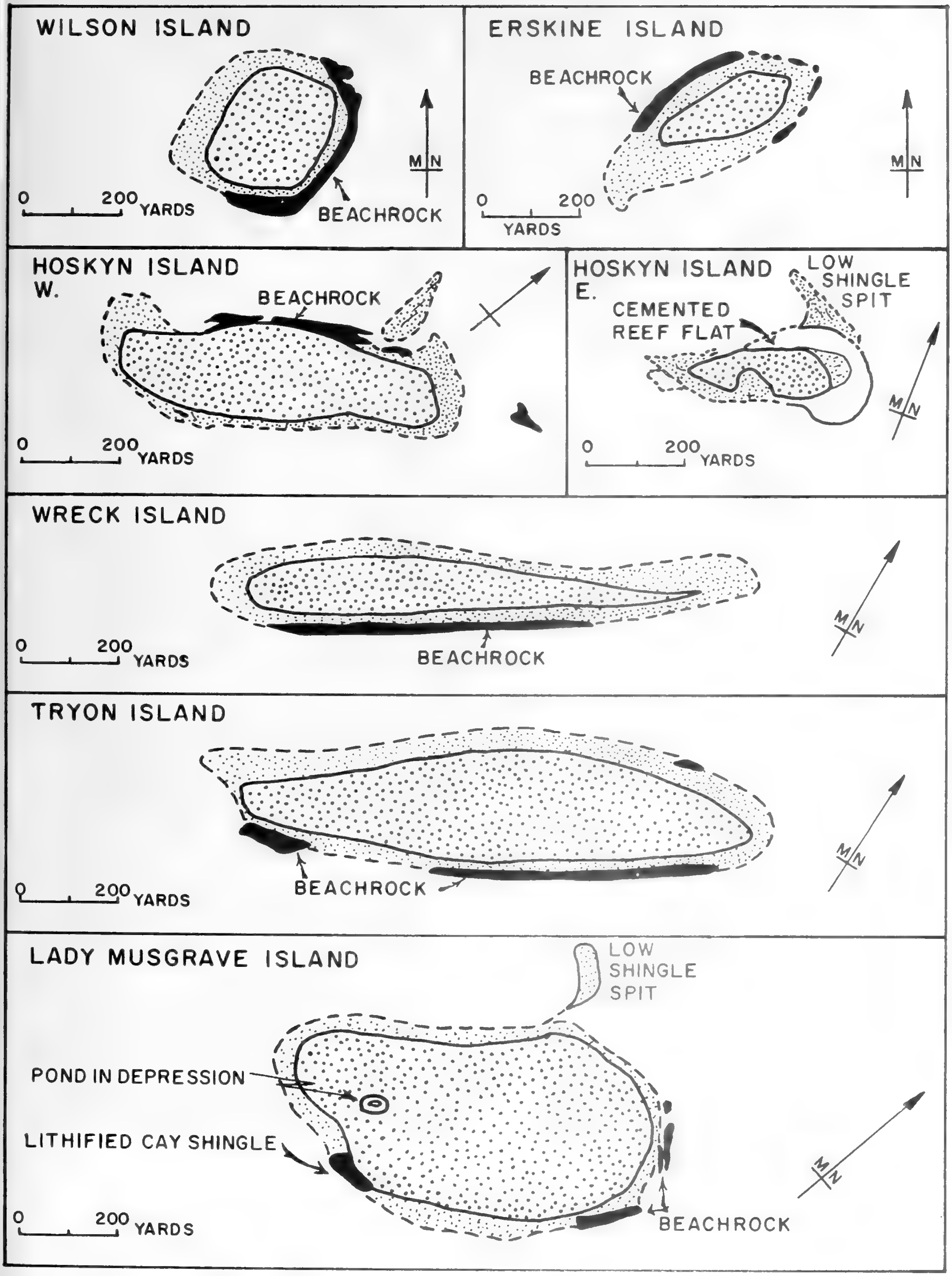


Fig. 7. Shape of coral cays in 1936 (after Steers, 1938): Wilson, Erskine, Hoskyn, Wreck, Tryon, and Lady Musgrave Islands.

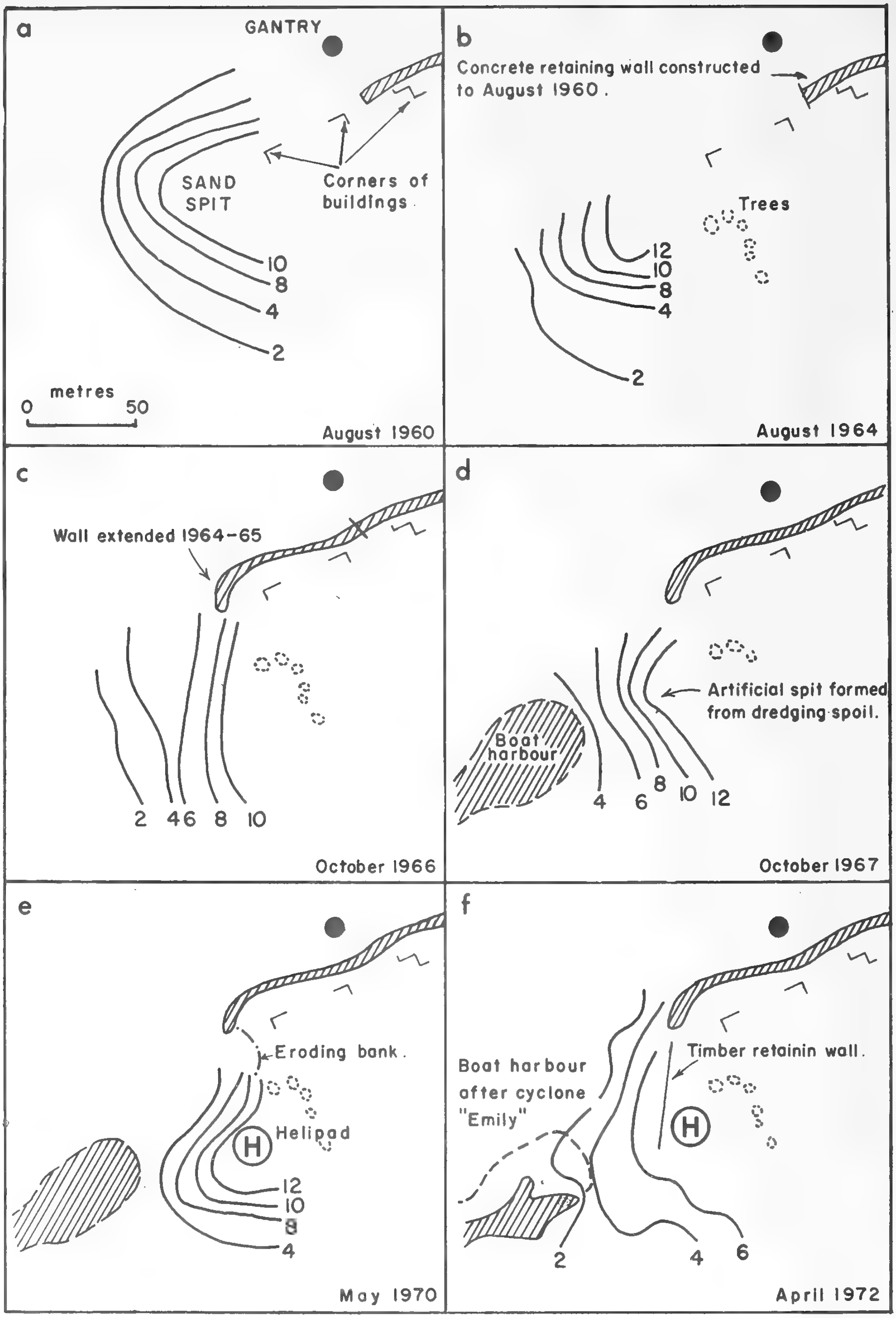
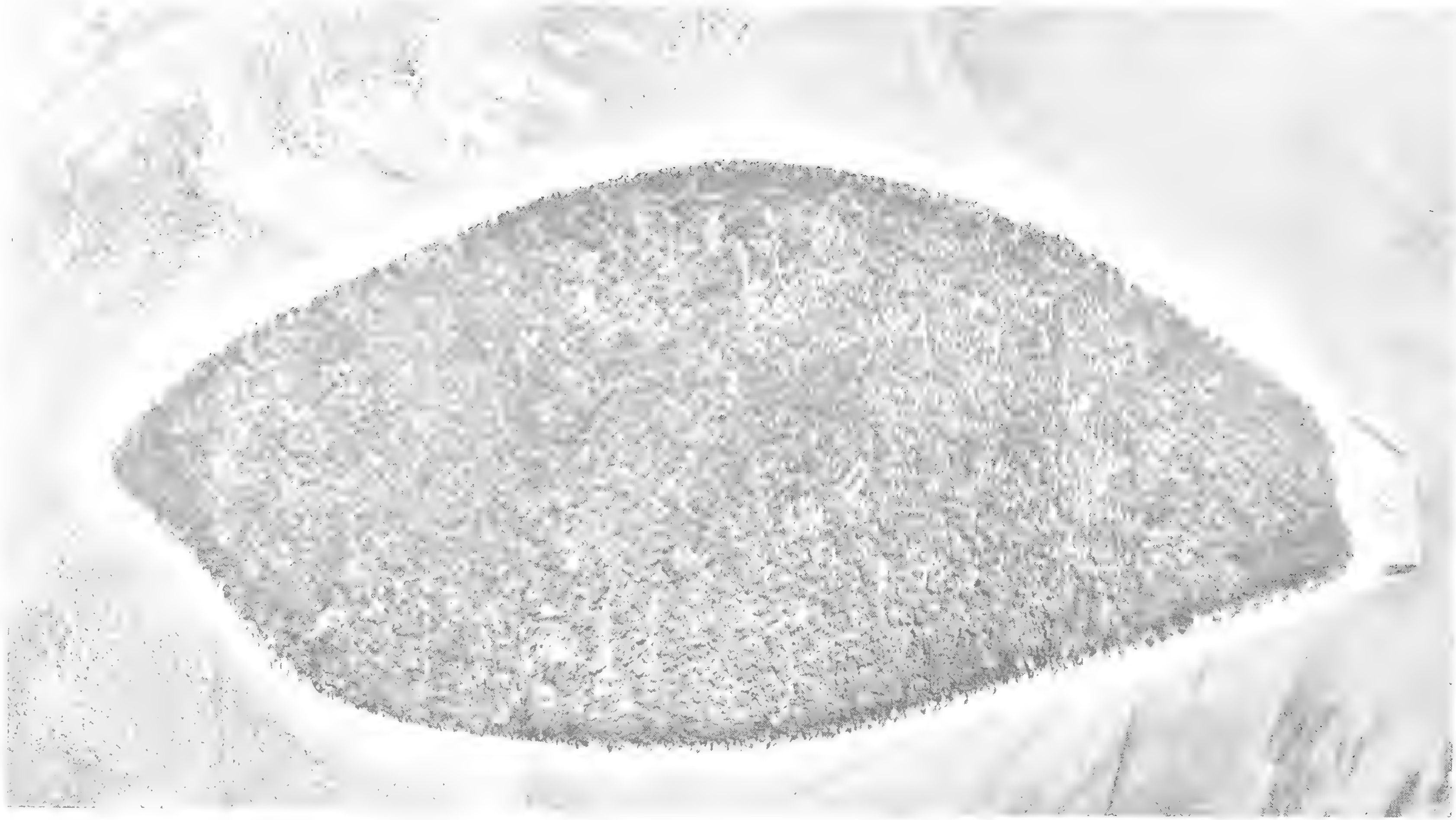


Fig. 8. Sequence of events connected with erosion of the western end of Heron Island (contours are in feet, 1ft.=30.5cm).

HERON ISLAND 0 300 METRES 25·9·73

PLATE 1

Plate 1. Heron Island. Vertical aerial photograph taken 25.9.73.



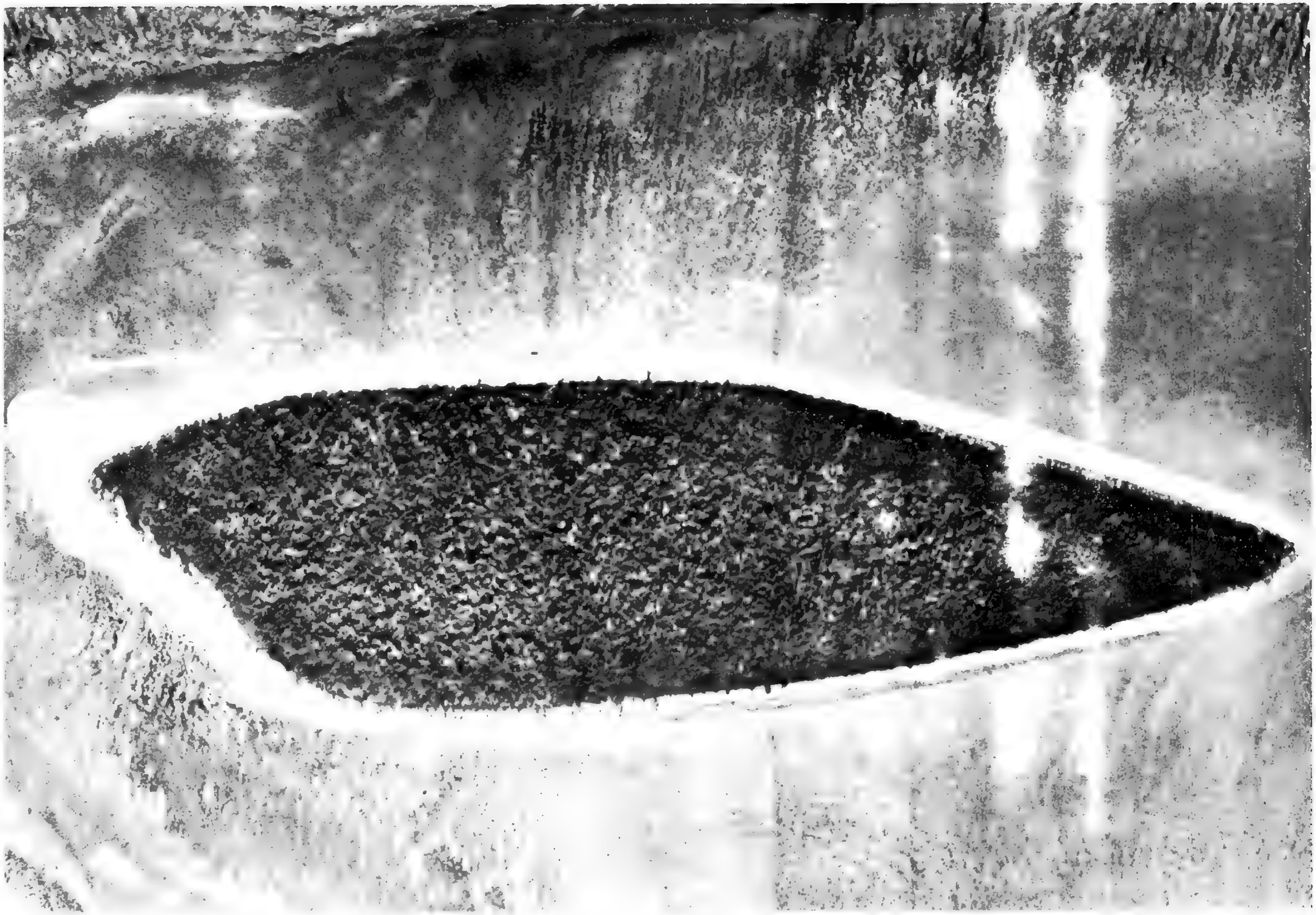
NORTH WEST ISLAND

0 300 METRES

24·6·72

PLATE 2

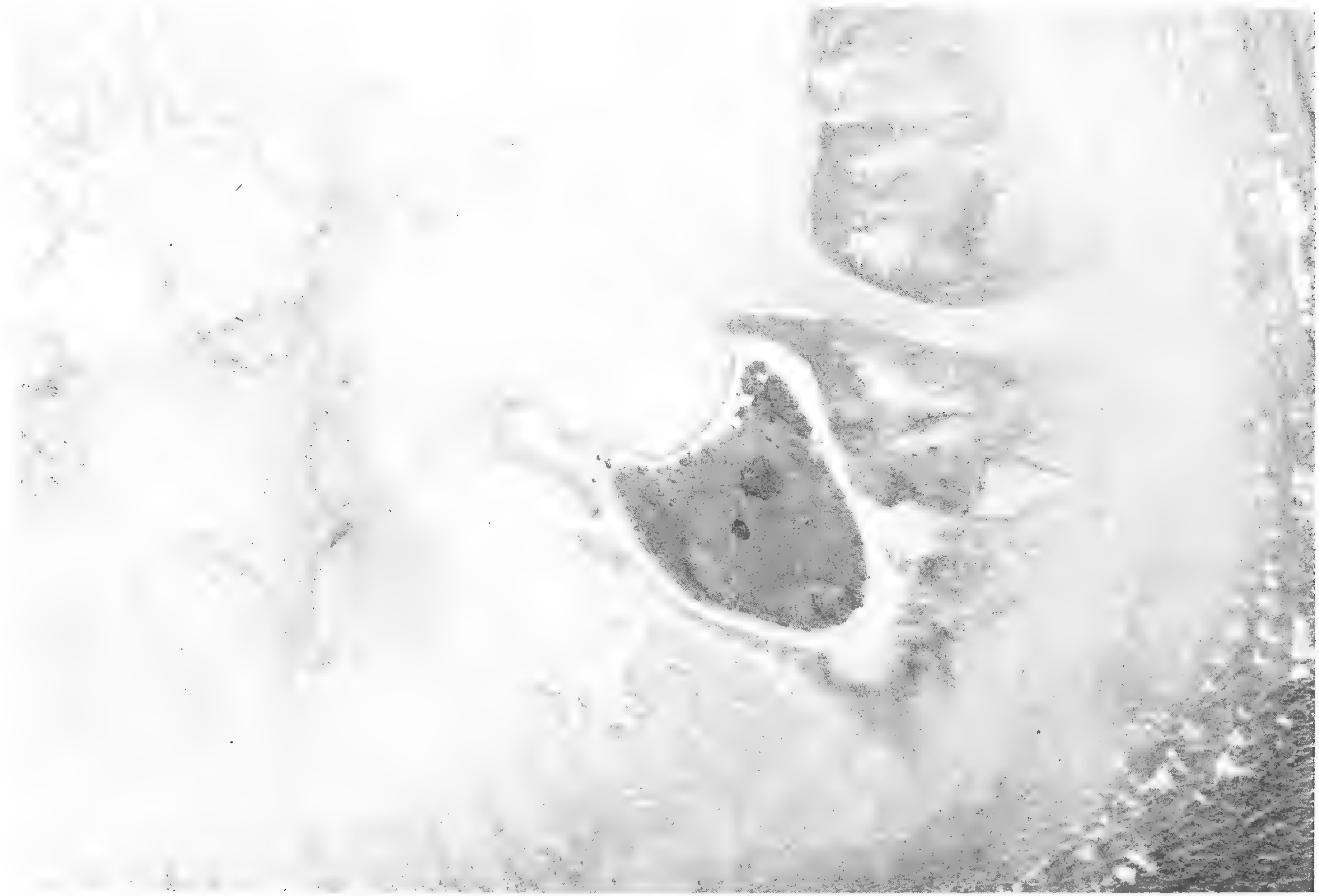
Plate 2. North West Island. Vertical aerial photograph taken 24.6.72.



MASTHEAD ISLAND   0 ——— 300 METRES   24·6·72

PLATE 3

Plate 3. Masthead Island. Vertical aerial photograph taken 24.6.72.



ONE TREE ISLAND   0 —— 300 METRES   25·9·73

PLATE 4

Plate 4. One Tree Island. Vertical aerial photograph taken 25.9.73.

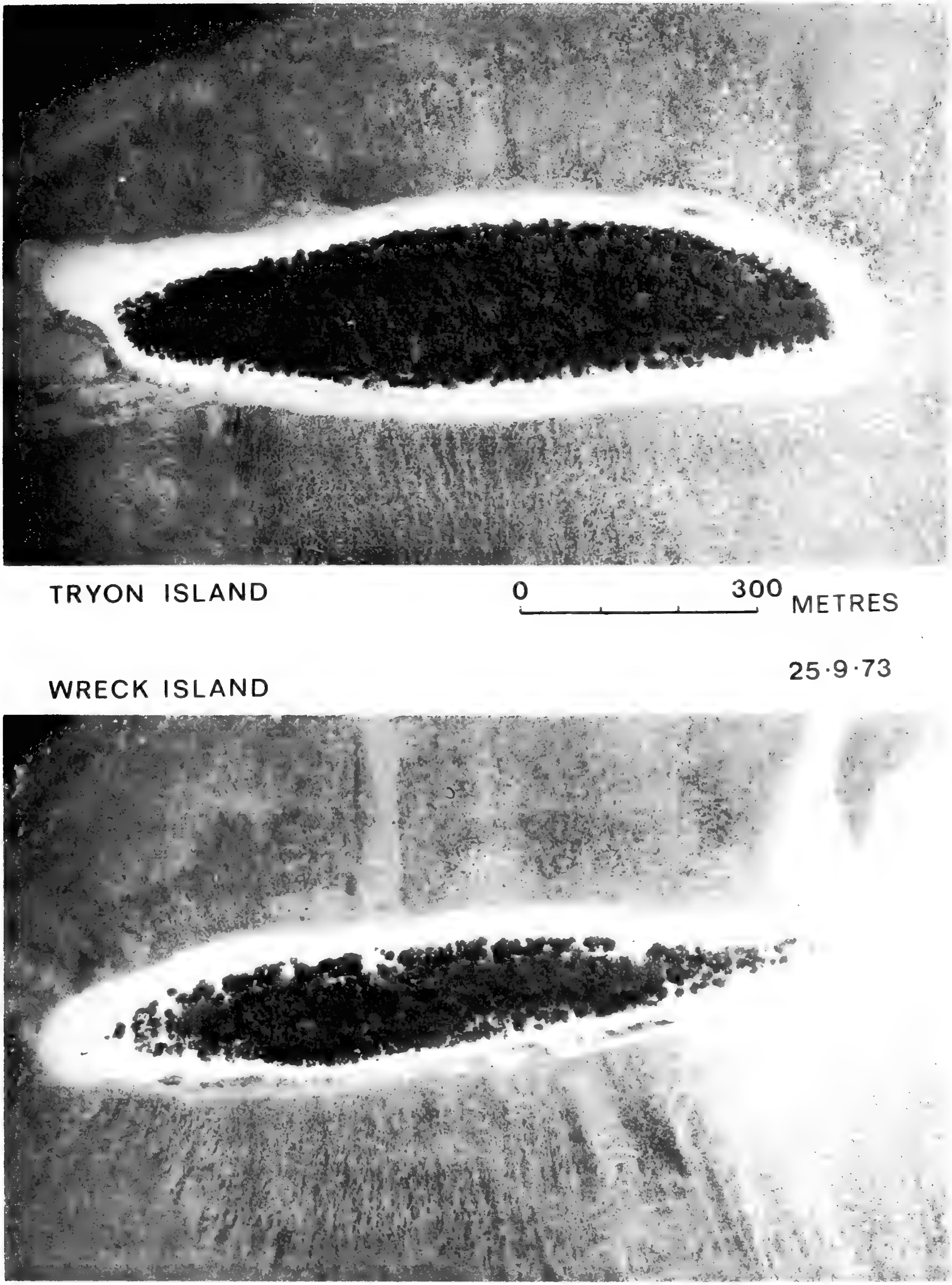


PLATE 5

Plate 5. Tryon Island and Wreck Island. Vertical aerial photograph taken 25.9.73.

NORTH ISLAND

0 300 METRES

WILSON ISLAND

25·9·73

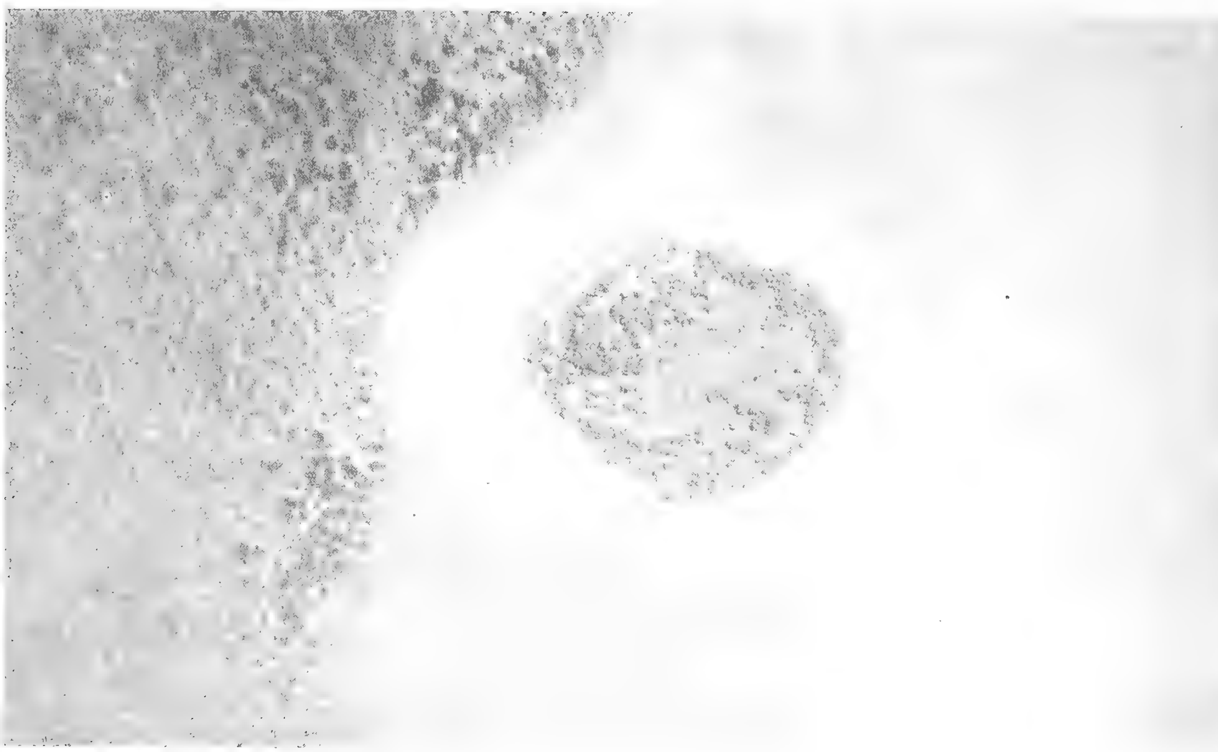


PLATE 6

Plate 6. North Island and Wilson Island. Vertical aerial photograph taken 25.9.73.

LADY MUSGRAVE ISLAND 0 300 METRES 25·9·73

PLATE 7

Plate 7. Lady Musgrave Island. Vertical aerial photograph taken 25.9.73.

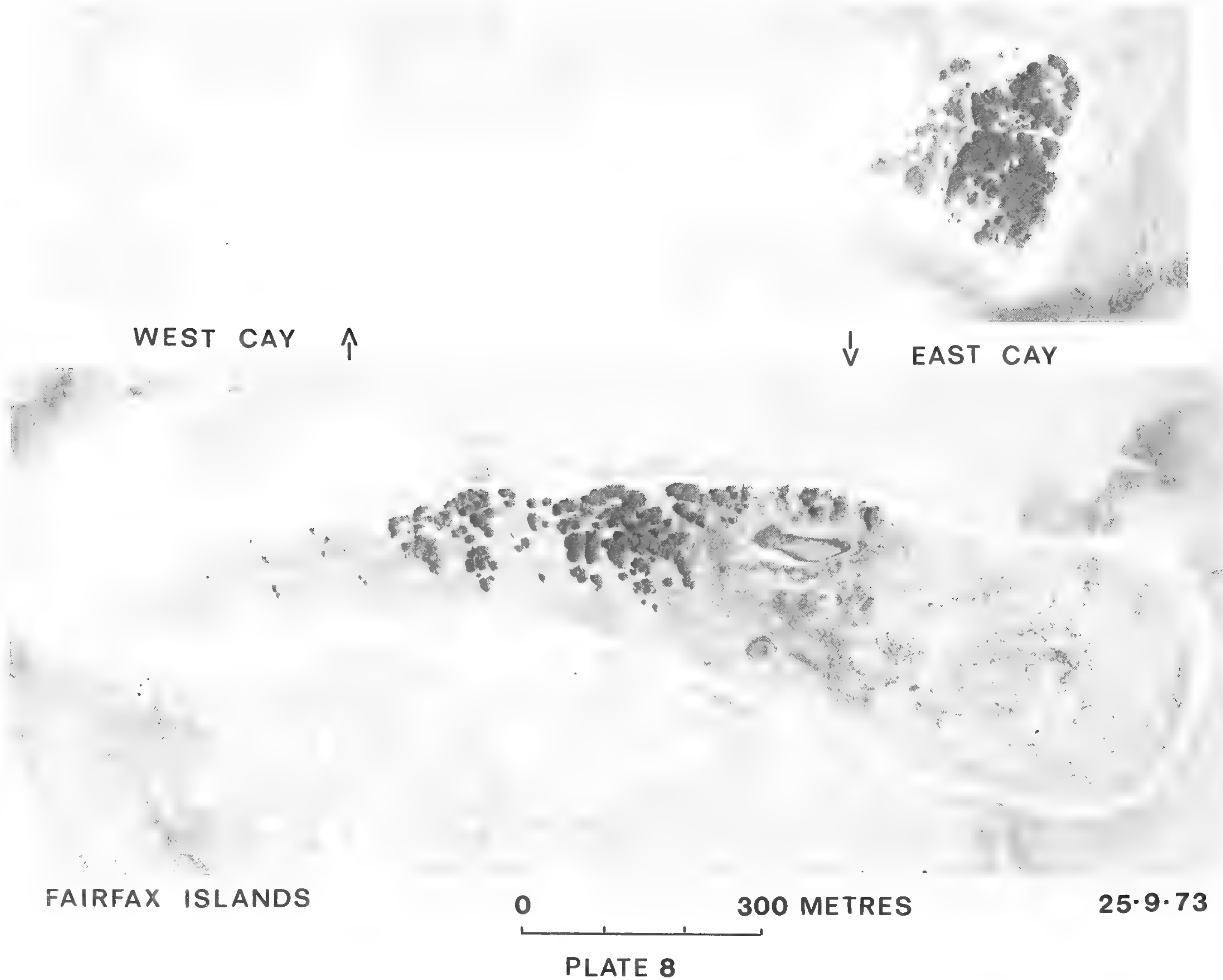


Plate 8. Fairfax Islands. Vertical aerial photographs taken 25.9.73.

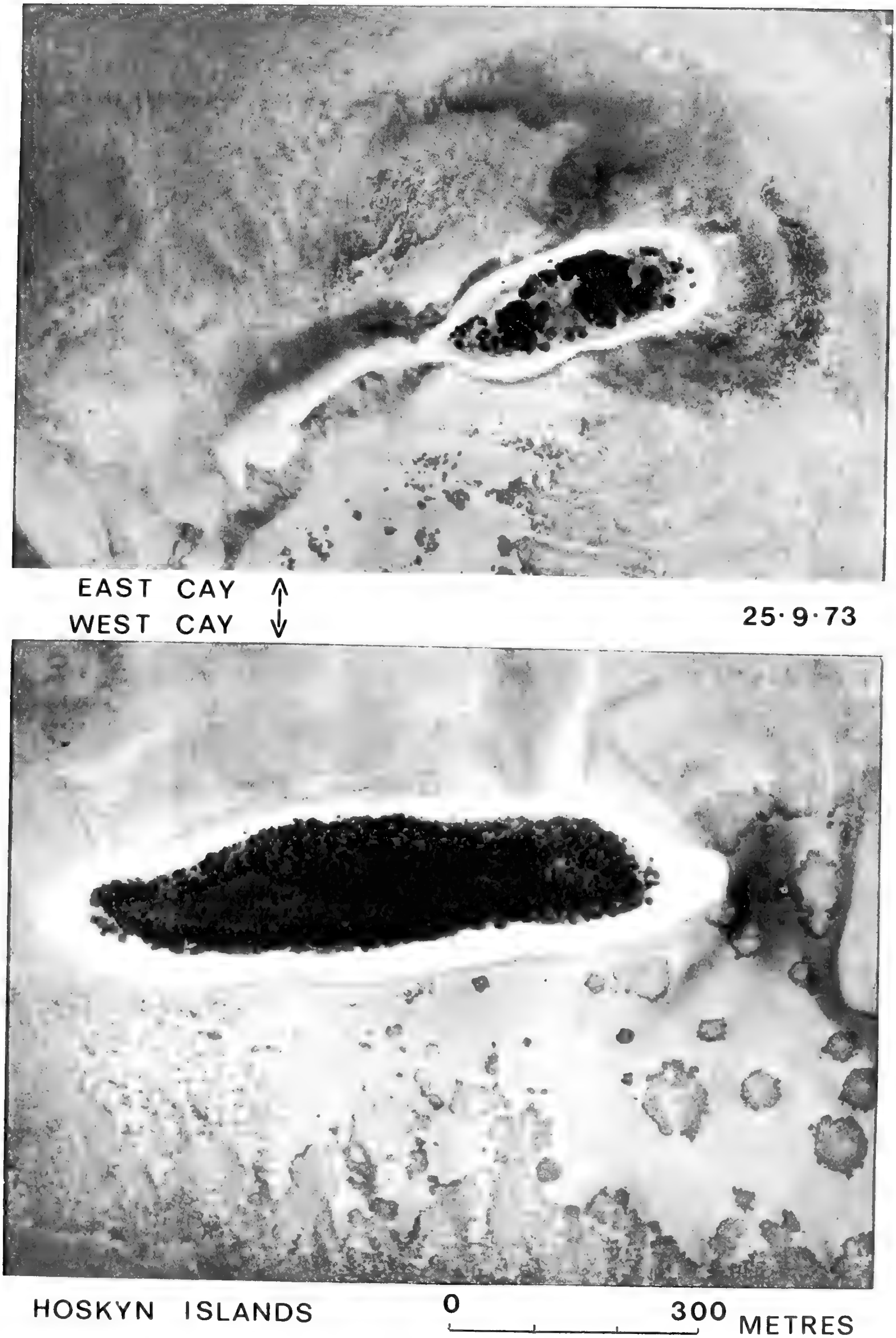
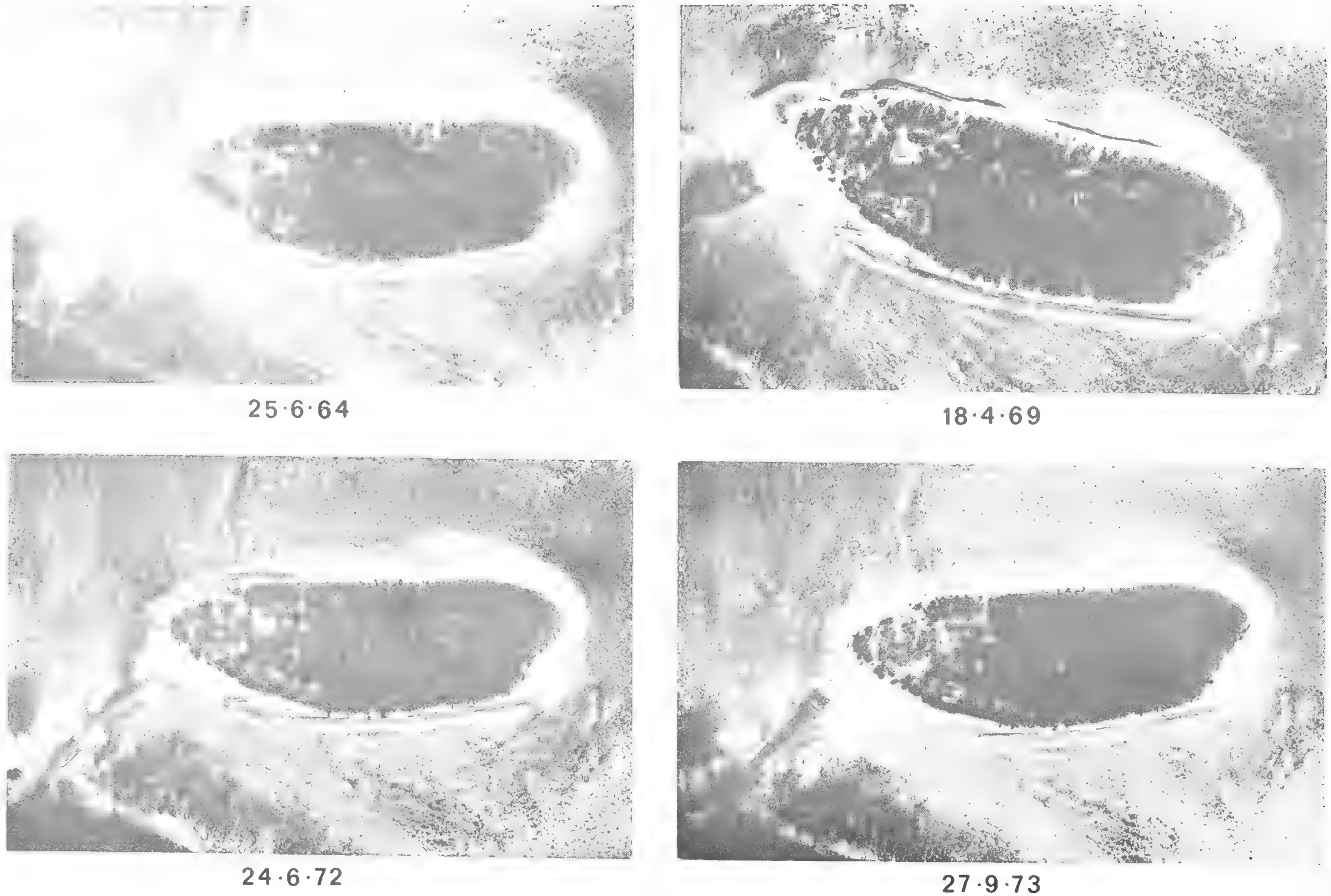


PLATE 9

Plate 9. Hoskyn Islands. Vertical aerial photographs taken 25.9.73.



EROSION OF HERON ISLAND — SEQUENTIAL PHOTOGRAPHS, 1964-73.

PLATE 10

Plate 10. Erosion of Heron Island. Sequential vertical aerial photographs 1964 to 1973.

ATOLL RESEARCH BULLETIN

NO. 196.

SUBMARINE CEMENTATION OF GRAINSTONE FABRIC, ST. CROIX, U.S. VIRGIN ISLANDS

by Lee C. Gerhard

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

SUBMARINE CEMENTATION OF GRAINSTONE FABRIC, ST. CROIX, U.S. VIRGIN ISLANDS

by Lee C. Gerhard

ABSTRACT

Submarine cemented carbonate sand nodules occur off the northeast coast of St. Croix, U. S. Virgin Islands. Cementation occurs as a 50 micron thick rim of aragonite needles over a thin micrite envelope surrounding the cemented grains. The locality in which the nodules are found is characterized by large ripples with the sand in nearly constant motion. The sand is medium-grained with practically no very fine sand and no micrite; neither are pellets present. Cementation is the result of physicochemical processes, forming a basic grainstone fabric.

INTRODUCTION

Nodules of cemented carbonate skeletal sand occur several centimeters below and at the sediment-water interface in 35 feet of water off the northeast coast of St. Croix, U. S. Virgin Islands (Fig. 1), just west of Cottongarden Point. These nodules lie in loose sand in a channel between and parallel to the main barrier reef and a second, outer, reef which does not reach the surface. Actively moving large ripples in the sand bottom (Fig. 2) characterize the entire bottom of this area, including both areas of cemented nodules and areas where no cementation occurs.

Individual nodules range from a few cemented grains to masses 8 centimeters in maximum diameter (Fig. 3). Grains in cemented nodules, nodule-bearing sands, and non-nodule-bearing sands are medium-grained, well-sorted, skeletal sands (Fig. 4). Percentage of individual skeletal constituents are approximately the same in the cemented material, nodule-bearing sands, and non-nodule-bearing sands (Table 1), and no clastic rock grains are present in either nodules or sands. Practically no micrite or pellets are present in any sample.

The cement is exclusively aragonite, determined by SEM and electron microprobe (Fred T. Mackenzie personal communication). Aragonite needles rim individual grains or small clusters of several grains. These rims average about 50 microns in thickness, with individual crystals

---

1 West Indies Laboratory, P. O. Annex Box 4010
Christiansted, St. Croix, U. S. Virgin Islands 00820

Current address: University Station
North Dakota Geological Survey
Grand Forks, North Dakota 58201

(Manuscript received August 1974--Eds.)

oriented normal or subnormal to grain boundaries (Fig. 5). Nearly every grain coated with the aragonite rim cement also has a thin micrite envelope below the aragonite. Cementation appears to be more complete in the centers of nodules than towards the exterior. Coarse particles are not cemented as well as those of near-mode size.

Sand ripples are symmetrical approximately 10 centimeters high from trough to crest, and the sand is in relatively constant motion during times of normal ocean swell (Fig. 2). Although the site of cementation was not been visited during storm swell times, logically the motion is even stronger then.

DISCUSSION

Many examples of modern carbonate cementation are known from a variety of geographic locations and environments. Nearly all of these examples are from "special" environments, that is, those with subaerial exposure, high salinity, or other non-normal marine characteristics. Most of these examples also involve either pellets in the sediment, micrite, or both. (A short note is not the place to give an extensive literature summary, but the papers and references of Macintyre et al, 1968; Bricker, 1971; and Sibley and Murray, 1972 are pertinent). Many of these previously described types of cementation occur on St. Croix in addition to the cement described here.

The major unique characteristics of the cementation described here are the occurrence of the cement in open, normal marine water, lack of pellets, lack of fine-grained sediment, and lack of a physical stabilizer. Cementation under these circumstances appears to be rare (Chilingar, et al, 1967, p. 186), although this cement is similar to that reported by Shinn (1969) in the Persian Gulf.

Granulometric analysis of nodule-bearing and non-nodule-bearing sands from the cement area provides little insight into the cause of cementation (Fig. 4). Both samples are well-sorted. Graphic standard deviation of the host sand is .40 phi, a well sorted sand (Folk, 1961) and the same parameter in the non-host sand is .50 phi, still a well-sorted sand. In both samples less than 5% of the total sample is less than 1.5 phi size, demonstrating that any fine sand or smaller particles either have been winowed out or have not been deposited. There is a sharp inflection in the cumulative curves of these samples between the most frequently occurring particle size and the next smaller 1/2 phi interval, although a much less marked inflection occurs to larger phi sizes. There is nearly no insoluble residue in these samples. The two samples are virtually identical in size and sorting except for the broader total size spread of the nodule-bearing area sample compared with the non-nodule-bearing area sample (-2.0 to 3 phi compared to -1.5 to 2.5 phi).

Constituent particle analysis of the two sand samples and the cemented sand itself sheds little additional information (Table 1). Coral content of each sample is about the same, no sample contains any pellets, and foraminifera, molluscs, and coralline algae form the remainder of the samples. The category "other" contains unidentified

grains, Halimeda, echinoderms, and other miscellaneous skeletal materials. Individual grain skeletal fabrics are unaltered. No discoloration is present nor are any of the cemented grains previously micritized.

Radiometric dating has not been done, but the cementation is interpreted to be modern because the cemented sands are identical to the sands currently being generated and transported in that environment, no pre-existing cemented carbonates of this kind have been discovered in this general area (or anyplace else on the island), no terrigenous (clastic) grains exist in the cemented or uncemented sands, although such grains are ubiquitous in nearshore or beach deposits (if the cemented nodules were remnants of earlier Holocene beachrock, they would contain large numbers of clastic grains), and grains are not pervasively micritized as is common in most of the St. Croix examples of cemented carbonate sands.

Cementation cause is probably purely physicochemical. Cement morphology is that predicted for normal marine subtidal cement by Badiozamani, Mackenzie and Thorstenson (1973) from laboratory studies (Mackenzie, personal communication). Sands are not stabilized at the surface, but about 4 centimeters below the troughs of ripples the sand is not moved except during uncommonly high seas. Cementation apparently takes place in the temporarily stabilized sand forming nodules, which are periodically moved by storm waves. No cemented layer has been found, so the nodules do not lie at rest for really extended periods of time, but are moved several times each year. Nucleation of cement appears to be preferential to grains with micrite envelopes. The resulting fabric (Fig. 5) is the precursor of typical grainstone fabric such as that of the Lower Ordovician Manitou Limestone (Gerhard, 1972, p. 18).

CONCLUSIONS

Cementation in basically unstabilized carbonate sands which have no appreciable micrite component and which are deposited well below low tide occurs. There appears to be no granulometric or constituent skeletal particle basis for cementation control, as nodule-bearing and non-nodule-bearing sands are virtually identical in size, sorting, and constituent particles. Cementation appears to be the result of purely physicochemical processes in temporarily stabilized carbonate sands. This example of submarine cementation is significant because it occurs under normal marine conditions, forms a grainstone fabric, and can be the source of grainstone fabric intraclasts in other textural type carbonate rocks.

ACKNOWLEDGEMENTS

I wish to thank Fred T. Mackenzie for analysis of the cement composition and for his discussions of the problem, and John Milliman who read the manuscript and made suggestions for its improvement. This is West Indies Laboratory Contribution No. 20.

REFERENCES CITED

Badiozamani, Khosrow, Mackenzie, F. T., and Thorstenson, D.C., 1973, Diagnosis of diagenetic environments of carbonate rocks by the fabric of their cement (Abstract).

Bricker, O. P., editor, 1971, Carbonate cements: The Johns Hopkins Univ. Studies in Geology, No. 19, The Johns Hopkins Press, Baltimore, Md., 376 p.

Chilingar, G. V., Bissell, H. J., and Wolf, K. H., 1967, Diagenesis of carbonate rocks, in Diagenesis in sediments, Chilingar, G. V. and Larsen, G., eds.; Developments in Sedimentology, v. 8, Elsevier Publishing Co., New York, p. 179-322.

Folk, R., 1961, Petrology of sedimentary rocks: Hemphill's, The University of Texas, 154 p.

Gerhard, Lee C., 1972, Canadian depositional environments and paleotectonics, central Colorado: Quarterly Colo. School Mines, v. 67, n. 4, p. 1-36.

Macintyre, I. G., Mountjoy, E. W., and D'Anglejan, B. F., 1968. An occurrence of submarine cementation of carbonate sediments off the west coast of Barbados, W.I.: Jour. Sed. Petrology, v. 38, p. 660-664.

Sibley, D. F., and Murray, R. C., 1972, Marine diagenesis of carbonate sediment, Bonaire, Netherland Antilles: Jour. Sed. Petrology, v.42, p. 168-178.

Shinn, E. A., 1969, Submarine lithification of Holocene carbonate cements in the Persian Gulf: Sedimentology, v. 12, p. 109-144.

Table 1. Constituent particle analysis of cemented nodules, nodule-bearing sand and non-nodule bearing sand.

	Cemented Nodule	Nodule-bearing Sand	Non-Nodule-Bearing Sand
Coral	50.6%	51.7%	51.1%
Foraminifera	20.6	16.5	26.5
Coralline Algae	14.5	18.9	12.9
Mollusc	11.6	8.2	5.7
Other	2.7	4.7	3.8
	100.0	100.0	100.0

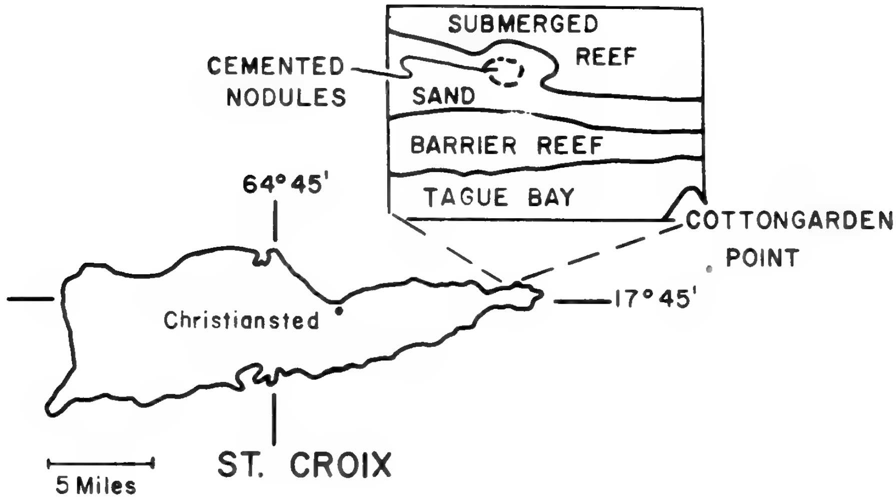


Fig. 1 Location map showing St. Croix and enlargement of area where cementation occurs.

Fig. 2 Sand ripples in cemented area, 35 feet deep, showing crestal sand in motion. Ripples are about 10 cm. high.

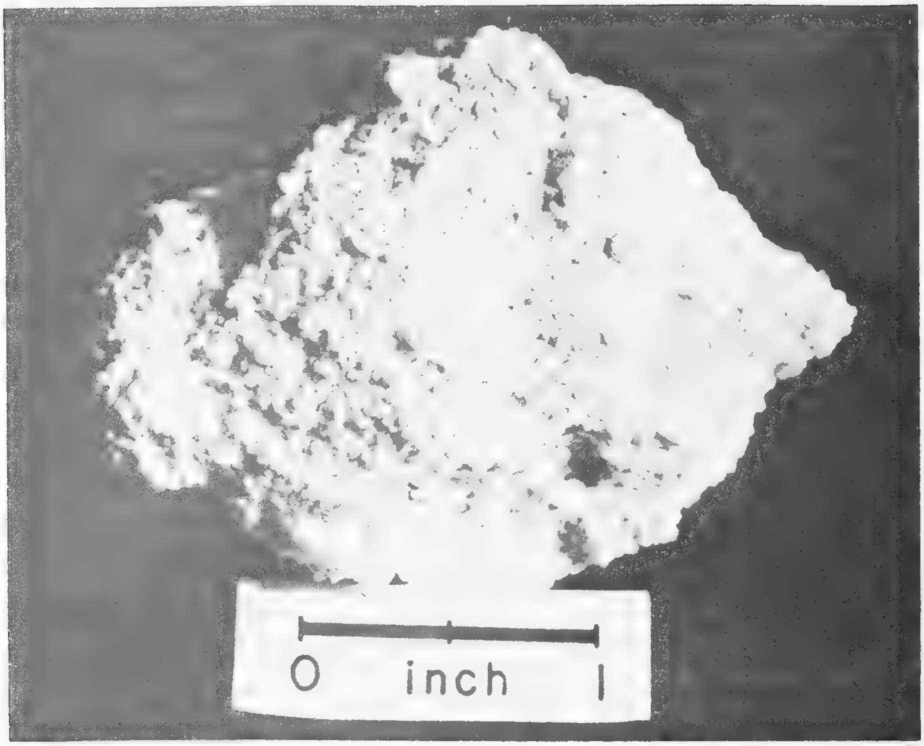


Fig. 3 Nodule of cemented sand from northwest of Cottongarden Point, St. Croix.

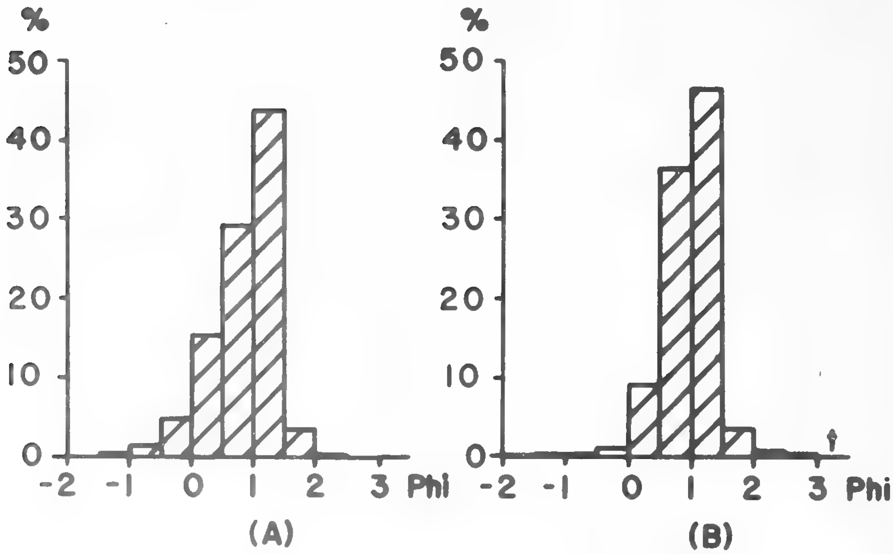


Fig. 4 Histograms of sand from non-cemented area (non-nodule bearing sand) (A) and cemented area (nodule-bearing sand) (B). Note the abrupt cutoff below 1.5 Phi size. Histogram drawn on 1/2 Phi intervals.

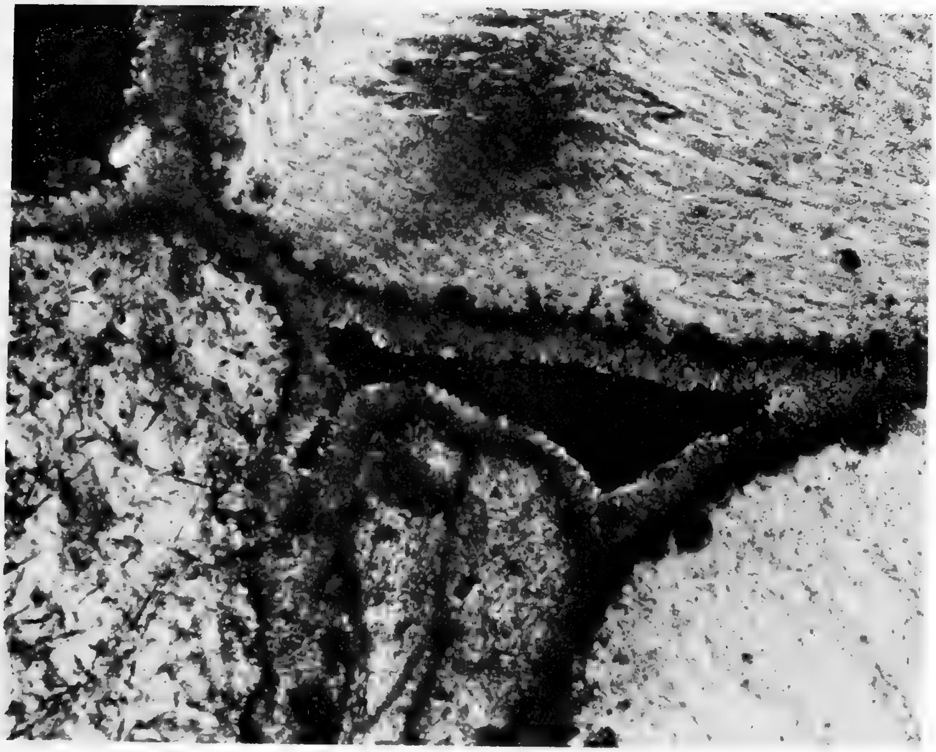


Fig. 5 Aragonite rims on micrite envelopes (dark grain coatings) cementing mollusc and bored coral sand grains. Field view is 1 mm. Crossed nichols.

ATOLL RESEARCH BULLETIN

NO. 197.

CHRISTMAS ISLAND (PACIFIC OCEAN): RECONNAISSANCE GEOLOGIC OBSERVATIONS

by Mark J. Valencia

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

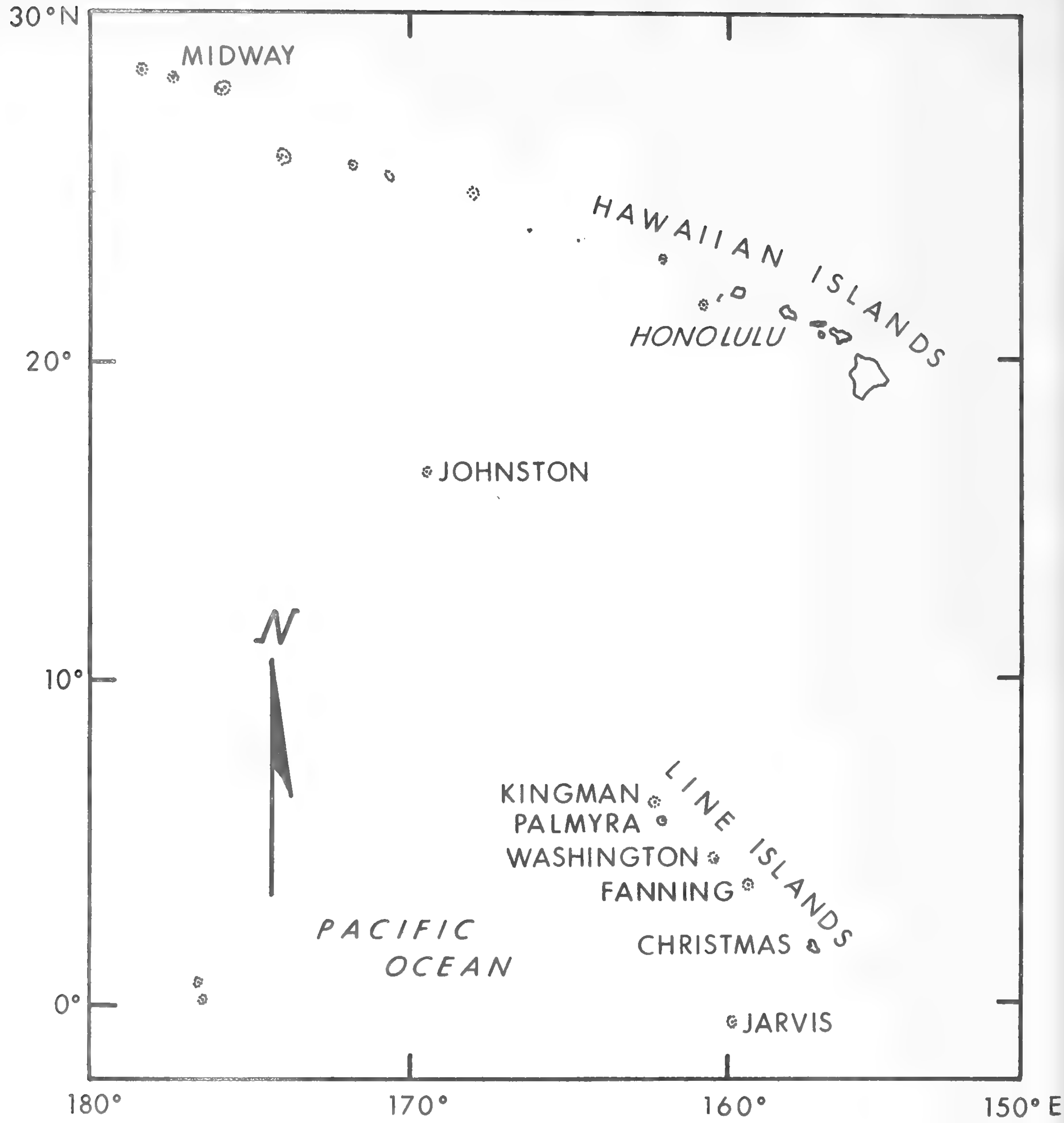


Figure 1. Location of Christmas Island.

CHRISTMAS ISLAND (PACIFIC OCEAN): RECONNAISSANCE GEOLOGIC OBSERVATIONS

by Mark J. Valencia[2]

INTRODUCTION

Christmas Island[3], the largest atoll in the world in terms of subaerial surface area, is located 200 km north of the equator in the equatorial dry zone (Schott, 1933) (Figure 1). The atoll is influenced by nearly constant 4 m/sec easterly winds and an average annual precipitation of 873 mm unevenly distributed in time (Jenkin and Foale, 1968). The shape of this southernmost of the northern Line Islands is like an elongated lobster claw with pinchers open to the northwest containing a semi-circular lagoon (Figure 2). Two passes, each nearly 2 km wide, connect the main lagoon to the ocean. Numerous sub-rectangular shaped hypersaline lakes are found to the east of the main lagoon as well as centrally along the elongated "arm" which extends 18 km to the southeast. Along the southeastern margin of the lagoon, the lakes are more numerous, and narrow channels connect some of them to the lagoon.

Wentworth (1931) and Wentworth and Ladd (1931) have reported reconnaissance observations on the general geology and sediments of Christmas Island, and detailed analysis of landform, soils, and hydrology is included in a report on the coconut-growing potential of the island by Jenkin and Foale (1968). The soils have been further investigated by Hammond (1969). Geologic data gathered by British

---

1 Hawaii Institute of Geophysics Contribution No. 588.

2 Hawaii Institute of Geophysics University of Hawaii, Honolulu, Hawaii 96822. Present address: UNDP Regional Offshore Prospecting in East Asia, c/o ECAFE, Sala Santitham, Bangkok 2, Thailand.

3 First western contact and name courtesy of Captain James Cook, December 24, 1777.

(Manuscript received June 1974 --Eds.)

scientists prior and subsequent to a 1957 nuclear test ("Operation Grapple") (Jenkin and Foale, 1968) conducted at 9,140 m above the southeast point, and by private guano and phosphate rock enterprises at various times, is acknowledged, but such data were for the most part unavailable to the author.

This paper reports 19 days of field observations and subsequent laboratory analysis of samples collected on two expeditions during March and November 1970 which investigated the *Artemia* (brine shrimp) aquaculture potential of Christmas Island. The expeditions were supported by National Sea Grant Program Grant 2-35-243 to P. Helfrich of the Hawaii Institute of Marine Biology, and by private individuals Seymour Gaines and Maurice Rakowicz. The aid of Fred Farrel, Glenn Fredholm, John Hance, and Mayo Ryder during the field investigations is gratefully acknowledged. Preparation of this paper was done while the author was with the Hawaii Institute of Geophysics.

General geology

Christmas Atoll surmounts the southeasternmost portion of a northwest-southeast trending volcanic ridge. The oceanic crust surrounding the ridge exhibits a broad moat and arch, with the arch crest some 240 km distant from the ridge axis. An archipelagic apron forms a smooth curve grading into the insular slope (Menard, 1964). An echo sounder profile of the southwestern slope shows "cone-like" features of probable volcanic origin (Ritchie, 1958). From the reef margin to a depth of 1300 m, the slope is quite steep (Jenkin and Foale, 1968). Coral thickness is 30 m at Motu Tabu (Figure 2) and elsewhere exceeds 120 m (Northrup, 1962; Jenkin and Foale, 1968; John Dryden, oral communication, 1971).

The island can be classified into six subaerial and two submarine landform units (Jenkin and Foale, 1968) on the basis of morphology and sediment type. Table 1 and Figure 3 summarize the geomorphologic characteristics of these landform units. Maximum elevation is 10.7 m above msl in the coastal dune unit along the Bay of Wrecks (Jenkin and Foale, 1968), although masses of reef rock distributed throughout the island's inland area exhibit a rather uniform height not exceeding 4 m above present sea level (Wentworth, 1931).

On the lagoon flats as much as a meter, but more commonly less than 10 cm, of beachrock (biosparudite, Folk, 1965) caps extensive areas of reef rock (coral biolithite and intrasparrudite) and unconsolidated medium calcirudite. Thicker beachrock sections indicating cycles of deposition and beachrock formation are exposed along walls of collapsed spring channels which feed many of the enclosed lakes (e.g., Lakes 16a, 19e, and 27b) and on islet edges within Lake 27a. Incipient beachrock formation was observed in dry areas of Manulu Lagoon and at 30 cm below the floor of an inactive spring channel entering Lake 19e.

In situ *Acropora* and *Tridacna* reef complexes are exposed along some lake margins. Repeated attempts at deep probing of the inter-lake margins betwen Lakes I4 and F7 and on the southeastern shore of 27a met

with an impenetrable horizon at approximately 6.5 m below the surface.

HYPERSALINE LAKES

The approximately 500 isolated and interconnected hypersaline lakes occupying 25 per cent of the total island surface area are of particular interest. In area the lakes range from the 16 km^2 Manulu Lagoon to puddles a few meters wide and centimeters deep (Figure 2). Frequently, differences in water level of a meter of more were observed between adjacent lakes, e.g., the water level of Lake EZ was 1.2 m higher than that of Lake 16A. These differences may be explained by variations in the water budgets of the lakes. Successive rings of shell berms or a border of evaporite crystals, either gypsum and halite or gypsum only, around most lakes indicated higher water levels in the past. Large fluctuations in lake surface area result from water level changes of less than a meter due to the generally shallow and gently sloping configuration of the lake basins. The lakes appeared to be at a relatively low level in their recent history; the expeditions took place during a prolonged drought. Lake levels were occasionally a meter or more below inactive spring channels (e.g., Lake 22), and Manulu Lagoon was observed to be partitioned into smaller interconnected lakes, in contrast to maps constructed by Jenkin and Foale (1968) from aerial photographs taken in the 1950's. Asymmetric basin profiles with recently exposed windward shores indicated active aeolian deposition in some lakes, e.g., in Lakes 27A and 16A.

A reducing environment, as indicated by the odor of hydrogen sulphide, was present immediately below the surface sediment in all lakes sampled. A semidiurnal increase in foam (reported previously by Wentworth, 1931), was observed along the leeward shores of many of the enclosed lakes; in the larger interconnected water bodies, linear patterns of foam extending from leeward to half the lake breadth indicated active Langmuir cells.

The lakes were of two basic types, subevaporite and evaporite, depending on the degree and duration of isolation from the main lagoon and ground water. Lakes actively depositing evaporites could be further classified according to the nature of the evaporite. Key indicators of lake types were bottom morphology, sediment type, and the presence or absence of a red gelatinous alga (S. A. Cattell, personal communication) apparently associated with medium hypersalinity, i.e., in this environment, approximately 200 to 300 o/oo.

Relatively isolated lakes, e.g., 19d, 19e, and 33a, were less than 2 m deep and had salinities greater than 300 o/oo. The lake bottoms were rough as a result of a network of polygonally arranged ridges exhibiting nearly 1 m of relief from ridge top to basin floor. The gypsum and halite crust was only 5 cm thick in Lake 33a and overlay red algae interspersed with halite crystals. A 1-m-wide band lacking evaporites or containing only a thin crust of gypsum indicated relatively low salinity seepage along the lake perimeters. (One could

determine those lakes which were actively receiving shoreline seepage by the presence or absence, in the evaporite ring, of halite crystals which are rapidly dissolved by contact with low salinity water.)

Other evaporitic lakes, e.g., 16a and 27a, had active, relatively low-salinity springs (36-41 o/oo) flowing from collapse features as much as 2 m deep eroded in the hardpan-capped reef rock, usually at the shore nearest the main lagoon. The total input rate of water from the several springs at the northern end of Lake 16a was estimated as less than 0.01 m^3/sec. Continuous long-term flow from one spring in Lake 16a was indicated by the presence of a distinctive, sharp, inverse temperature gradient previously noted by Northrup (1962).

These spring-fed evaporitic lakes, also less than 2 m deep, were characterized by a smooth bottom consisting of a 1-cm thick crust of halite cubes overlying at least 1 m of red algae mixed with halite crystals. Core 16a-1 (Table 2) from the windward shore exhibited a regressive sequence, whereas a longer core (16A-2, Table 3) revealed cyclic variation in sediment type. A core of slightly pebbly, coarse sandy calcareous mud (Folk, 1965) from the windward shore of Lake 27a had a minimum sedimentation rate of 1.8 cm/yr for the past 15 years. This measurement is based on gieger count detection of the 1957 nuclear test horizon at 28 cm below the core top (D. Knutsen and R. Buddemeier personal communication, Figure 4). The sedimentation in this core appeared normal and continuous for this location (Table 4).

Lakes that lacked gypsum and halite deposits, e.g., E, F, and I series, were interconnected by narrow channels to the main lagoon. Channel morphologies for lakes in the F series appeared to represent stages in a developmental cycle. Incipient channel development was possibly occurring between Lakes F6 and F7 as indicated by a 2-m-wide, 20-cm-deep water connection between the two lakes over the beach-rock-capped divide. Perhaps during and after infrequent heavy rain, water of low salinity, undersaturated with respect to calcium carbonate, initiates dissolution of the hardpan while flowing between lakes. After an unusually heavy rain, a rise in water levels in the lakes resulting in submerged interlake boundaries has been observed (George Krasnick, personal communication). Once the crust is weakened, the silt and clay would be eroded by the water flow, leaving a sediment dominated by pelecypod and *Acropora* fragments. A more advanced stage in this process was represented by an inactive channel between F2 and F4. At the F2 end, the beachrock crust was absent along 20 m of channel length and the channel was filled with unbroken pelecypod shells. Once the channel bottom is eroded below the water table (0.5 to 1 m on the lagoon flat, Jenkin and Foale, 1968), extensive widening may occur from groundwater seepage and undercutting, as evidenced by blocks of beachrock several meters in diameter slumped into one of the channels. An example of the next stage of this cycle of channel activity was represented by an inactive channel between F4 and F5. A hypersaline puddle was bounded by a shell shoal at the F4 end and a shell berm at the F5 end. As the water evaporates from the puddle, and by capillary evaporation elsewhere, beachrock will form to stabilize the unconsolidated shells.

Line soundings in Lake F2 recorded depths up to 6 m, and fathometer records indicated submerged isolated patch reefs in the F series lakes (Helfrich, *et al.*, 1973). A salinity increase from the main lagoon edge to the interior of interconnected lake series revealed the probable cause of reef and invertebrate extinction in the lakes farthest from the lagoon. A general salinity increase in a northeast-southwest direction for interconnected lake series reflected the influence of permanent fresh-water lenses in the northeast. For example, springs entering lake Alb had salinities of 24 and 16 o/oo. (Helfrich, *et. al.*, 1973).

Nearshore bottom-sediment type varied considerably in these "open" lakes but the dominant type for F series lakes was a sandy, pebble gravel of pelecypod and *Acropora* fragments. The berms around the lake margins consisted of well-sorted pelecypod and gastropod pebble gravel. In windward nearshore Lake Fla, a core penetrated 16 cm of pink organic "fluff" down to an extinct pelecypod bed. Windward sedimentation or reworking is fairly rapid in these open lakes, as evidenced by ruts partially filled and smoothed by the pink organic "fluff" and aeolian silt. These ruts were made 5 months previously by a landrover used by the expedition.

Lagoon

The rectilinear pattern of patch reefs and concomitant depositional upbuilding extended into the lagoon from the southeastern and eastern margins (Helfrich, unpublished data). The margin of the lagoon was not easily defined in these regions due to complexes of broad tidal flats, peninsulas, reefs, and islands. A maximum lagoon depth of 7 m is approximately equivalent to that of the F lakes. In addition to aeolian deposition, large amounts of fine and medium calcareous debris transported from the seaward leeward shore through the passes results in a buildup of the lagoon floor (Wentworth, 1931). Continuous rapid shoaling of the northern pass is evident from its dredging history (Jenkin and Foale, 1968). In spite of high sedimentation rates, patch reef development is more frequent in sheltered areas, such as along the eastern margin, where the substrate is more stable than elsewhere.

Phosphate

Apatite, identified in the field and subsequently confirmed by X-ray analysis (W. Burnett, personal communication), occurs to a depth of 0.5 to 1 m as peripheral and fracture rinds in a 2-acre outcrop of beveled and severly eroded beachrock situated in the lagoon flat unit in the north near Lake 1B (P, Figure 2). This observation is interesting in relation to Hutchinson's (1950) hypothesis that several thousand years ago, the equatorial rain belt was centered over Christmas Island, i.e., farther south than at present. His hypothesis was based on the supposed present day absence of evidence of phosphatization on relatively dry Christmas Atoll in contrast to the present day occurrence of phosphate rock on wetter islands to the north and south.

However, this one occurrence of phosphate rock does not account for the amount of phosphatization that might be expected from the combination of low annual precipitation and the present and presumably past deposition of 200 tons/yr of guano as estimated from bird populations (Helfrich *et al.*, 1973). Avian Mining Company of Canberra, Australia drilled a test hole to 40 m on Motu Tabu, apparently without encountering commercial deposits of apatite (John Dryden, personal communication).

The curious scarcity of both guano and phosphate rock deposits could be ascribed to bird behavioral patterns and to leaching by occassional heavy rains (Helfrich *et al.*, 1973).

Hypothetical geologic development

Variations of rates and directions of spreading within the oceanic crust emanating from the East Pacific Rise produce zones of crustal weakness. During the formation of the Hawaiian Ridge, volcanism progressed from northwest to southeast along such a zone, so the southernmost volcanically active island of Hawaii is not only the youngest but also the largest. The northwest-southeast structural trend of the volcanically extinct Christmas Island ridge and the large size and position of Christmas Atoll relative to the other Northern Line Island atolls to the northwest evoke a comparison with the evolving Hawaiian Ridge. If a similar mechanism of origin applies to the Christmas Island Ridge, the volcanic complex upon which Christmas Atoll has formed is then the youngest of the northern Line Islands, having developed in early Cenozoic time (Menard, 1964).

The basic shape of an atoll is largely dependant on the morphology of its volcanic basement (Wiens, 1962) but the surficial detail is controlled by sea level fluctuations and climatic and tectonic influences. The irregular shape of Christmas Atoll is probably a result of the arrangement of volcanic peaks similar to those observed on the southwest insular slope. The development of the major geomorphologic features is a result of linear patch reef growth, and a progressive westward and northward infilling of the main lagoon, perhaps aided by slow northwestward tilting of the entire atoll. Roy and Smith (1970) speculate that Fanning Atoll, 320 km to the northwest, has tilted up to the west, whereas the nearest land to the south, Jarvis Atoll, 420 km to the southwest, has a filled lagoon floor 2.5 m above sea level with evaporite crystals in the deepest depressions thus indicating recent emergence (Wiens, 1962).

Wiens (1962) has proposed a hypothetical model of the morphological cycle of an atoll with changing sea level (Figure 5). His lowest reef profile represents the appearance of an atoll at the end of the last low stand of the sea (Wisconsin). At that time the emerged reef, which once had been 100 m higher than the Wisconsin level, was dissolved and mechanically eroded so that only portions of the reef periphery (A) and small lagoon highs (D) remained above sea level. At this stage, the lagoon bottom (C) was at sea level. Also produced was a fringing reef flat (B) with an outer algal ridge and a live reef-front with a well-

developed wave-cut bench and a windward spur and groove system.

During the post-Wisconsin eustatic rise of sea level, a rectilinear pattern of *Acropora* and *Tridacna* patch reefs developed on the immersed lagoon floor of Christmas Island parallel or transverse to northeast and southeast modes of wind direction. At present, easterly winds predominate with a minor mode from the southeast, and linear patch reef development transverse to the easterly mode is occurring in the windward lagoon. However, the pattern of lake margins, presumably underlain by reefs, hints at past northeast and southeast wind modes. Linearly arranged patch reefs oriented downwind or, more rarely, transverse to the main wind direction are present in several atoll lagoons (Wiens, 1962) including a rectilinear pattern in Fanning Atoll lagoon (Roy and Smith, 1970). Linear patch reef development was due possibly to more rapid reef growth in divergences of Langmuir cells or to a rectilinear base of sand dunes developed during the Wisconsin low stand. In the latter scheme, patch reefs would have been less well-developed in the leeward than the windward lagoon due to more extensive bar development nearer the windward sediment source. Differential growth rates of coral and coralline algae between the seaward and leeward reefs, possibly aided by northwestward subsidence, resulted in the northwest passes.

As sea level rose to a maximum 2 m level within the last 5000 years (Fairbridge, 1952, 1961), Christmas Island was almost entirely submerged, although lagoon patch reef development kept pace with the rising sea level. During the brief still-stand and the subsequent eustatic fall of sea level, the reefs were planed off, supplying sediment to the emerging lakes. Beachrock formation on leveled, exposed reef tops incorporated bivalves and other biogenic debris. Aeolian sediment, derived from the emerged windward coastal plain and the seaward beaches, formed the coastal inland and lagoon dunes and also accumulated in the lake basins, along with autochthonous biogenic sediment. Wave transportation and deposition of sediment was effective in plugging breaches in lake peripheries. The lakes progressively filled and became isolated from the main lagoon, although some ephemeral shallow channels were maintained by tidal flow. The increasing salinity curtailed reef and invertebrate growth, and bivalve and gastropod shells accumulated in berms on the leeward lake shores. The windward lagoon is now in the incipient stage of this process of hypersaline lake formation, whereas the interconnected lakes are indicative of the next stage. The completely isolated lakes continue to shoal due to precipitation of evaporites, principally gypsum and halite.

REFERENCES

Fairbridge, R. W., 1952. Multiple stands of the sea in post-glacial times. *Proc. 7th Pacific Sci. Congr.*, 3.

Fairbridge, R. W., 1961. Eustatic changes in sea level. *Physics and Chemistry of the Earth,* 4: 99-185.

Folk, R. L., 1965. *Petrology of sedimentary rocks:* Hemphill's, Austin, Texas, 159 pp.

Hammond, T. T., 1969. *The characterization and classification of the soils of Christmas Island:* Unpublished, Univ. Hawaii M. S. thesis, 109 pp.

Helfrich, Philip, in collaboration with John Ball, Andrew Berger, Paul Bienfang, S. Allen Cattell, Mari Dell Foster, Glen Fredholm, Brent Gallagher, Eric Guinther, George Krasnick, Maurice Rakowicz, and Mark Valencia, 1973. The feasibility of brine shrimp production on Christmas Island. *Univ. Hawaii Sea Grant Tech. Rept.* TR-73-02, 173 pp.

Hutchinson, G. E., 1950. The biochemistry of vertebrate excretion. *Bull. Amer. Museum Nat. Hist.* 96: 1-554.

Jenkin, R. N. and Foale, M. A., 1968. An investigation of the coconut-growing potential of Christmas Island. Ministry of Overseas Development, Resources Division, Directorate of Overseas Surveys, Tolworth, Surrey, England, *Land Resources Study* No. 4, vol. 1.

Menard, H. W., 1964. *Marine Geology of the Pacific.* McGraw-Hill Book Co., London, pp. 79, 92.

Northrop, John, 1962. Geophysical observations on Christmas Island. *Atoll Research Bull.* 89: 1-2.

Ritchie, G. S., 1958. Sounding profiles between Fiji, Christmas and Tahiti Islands. *Deep-Sea Res.,* 5: 162-168.

Roy, K. J. and Smith, S. V.,1970. Sedimentation and coral reef development in turbid water: Fanning Lagoon. *Hawaii Institute of Geophysics Report* HIG-70-23: 61-76.

Schott, G., 1933. The distribution of rain over the Pacific Ocean. *Proc.5th Pacific Sci. Congr.* 3: 1887-1890.

Wentworth, C. K., 1931. Geology of the Pacific Equatorial Islands. *Bernice P. Bishop Museum Occ. Pap.* IX, 15: 3-25.

Wentworth, C. K. and Ladd, H. S., 1931. Pacific Island sediments. *Stud. Nat. Hist. Iowa Univ.,* 13: 1-47.

Wiens, H. J., 1962. *Atoll environment and ecology:* Yale Univ., 532 pp.

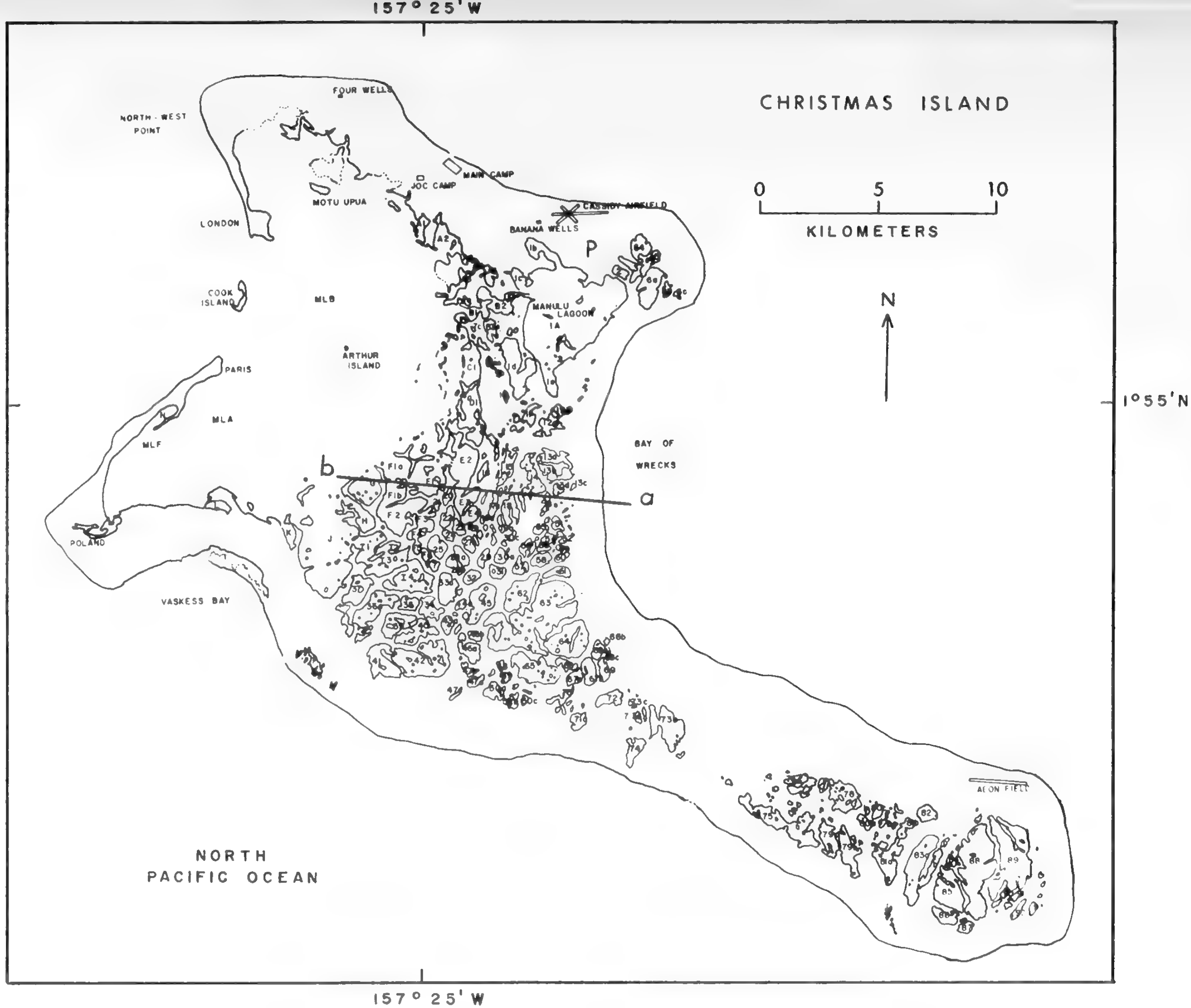


Figure 2. Map of Christmas Island with labels for saline lakes. P is outcrop of phosphate rock (apatite): a---b is line of section in Figure 3.. Letters denote lake series which are connected to the lagoon, and numbers indicate isolated water bodies (from Helfrich *et al.*, 1973).

Table 1. Characteristics of submarine and subaerial landform units of Christmas Island (summarized from Jenkin and Foale, 1968).

Unit	Description
Seaward reef	Platform 30-120 m wide around entire perimeter; widest on northern coast. Groove and spur structure on seaward margin; better developed on leeward (western) coast. Windward coast has algal ridge exposed 50 cm at low tide.
Seaward beach	Leeward beach 6 m wide; windward beach 2 m wide; maximum exceeds 10 m. Leeward beach composed of well-rounded, well-sorted medium coral and mollusk sand. Windward beach is steeper and composed of rounded coral "shingles".
Beach crest, coastal dunes, and boulder rampart	Beach crest is 2 m side, 3-4 m high, coral sand ridge along westernmost end of northern coast and parts of southern coast. Beach crest replaced by extensive coastal dunes up to 50 m wide and 6-10.7 m high along parts of northern coast and southwestern corner of Bay of Wrecks. Coastal dune sand is derived from seaward beach sand. Angular coral boulders 15 to 50 cm in diameter form a rampart up to 30 m wide and 2-3 m high along parts of the Bay of Wrecks and the Southeast Peninsula.
Coastal plain	Plain is 100-200 m wide and consists of coral sand, gravel, and boulders up to 10 cm in diameter. Occasional silted-up or evaporated land-locked lagoons; e.g., lagoon behind Cecile Peninsula.
Central ridge and inland dunes	Represents former coastline; beach sands mechanically similar to seaward beach and aeolian coral sand augmented by organics from nesting sooty terns. Coral fragments up to 10 cm in diameter occur below 150 cm. Central ridge occurs extensively in the north, less extensively near the southern and southwestern coasts, and infrequently in the east and southeast. Central ridge 4 m above mean sea level at New Zealand airfield, augmented by aeolian sand from lagoon flats. North of Poland, central ridge is predominantly derived from aeolian lagoonal flat sand. Central ridge 5 m above mean sea level in north and around Bay of Wrecks; coral sand derived from seaward beach and beach crest. Inland dunes in Four Wells area and Auverne Sandhills in south.

Table 1. (Continued)

Lagoon scarp and lagoon dunes	Scarp is 1 to 1.5-m drop over a 12-m distance between central ridge and lagoon flats; where central ridge absent, no scarp occurs. North of Poland and London, scarp is replaced by line of lagoon dunes on lagoon edge of central ridge; dunes formed from aeolian sand derived from lagoon beach and flats.
Lagoon flat and lagoon beach	Flats less than 1 m above mean sea level enclose hypersaline lakes and border the main lagoon on the north, east, and south; they also occur along the interior of the Southeast Peninsula. Sediment on lagoon flats to the north of the main lagoon and near the Southeast Point is generally fine-to-medium coral sand with coral boulders up to 10 cm in diameter below 30 cm. Hardpan (beachrock) up to 25 mm thick covers lagoon flat on eastern and southern sides of main lagoon and around hypersaline lakes in center of Southeast Peninsula; sediment beneath hardpan similar to uncovered sediment elsewhere in lagoon flats. Near the bathing lagoon and on Motu Tabu, Motu Upua, and Cook Island, coarser coral sand covers the finer lagoonal sediments. Gently sloping beaches composed of finer-to-medium coral sand occur along the western coast of the main lagoon and along the western edge of Manulu and the Isles Lagoon.
Lagoon reef	Moderately well-developed in sheltered eastern main lagoon; patch reefs in western main lagoon. High sedimentation rate and shifting substrate in shallow (7 m depth maximum) lagoon inhibit coral development.

Table 2. Megascopic description of sediments in Core 16a-1.

Depth (cm)	Description
0 - 2	Pebble-size halite crystals in groundmass of green alga-calcium carbonate-halite mud; some pebble-size pelecypod fragments.
2 - 10	Bimodal sediment: whole pebble- and cobble-size gastropod and pelecypod shells in groundmass of sand-size shell fragments.
10 - 16	Coarse sand-size gastropods; rounded and subangular pebble-size shell fragments partially cemented together with calcium carbonate; occasional entire leaves.
16 - 30	Scattered coarse sand-size gastropods in white calcium carbonate mud matrix.
30 - 59	Occasional gastropod and pelecypod fragments in pink calcium carbonate mud matrix.

Table 3. Megascopic description of sediments in Core 16a-2.

Depth (cm)	Description
0 - 4	Brownish-green algal mud; occasional pelecypod fragments.
4 - 9	Brownish-pink algal mud; occasional pelecypod fragments.
9 - 10	Pink algal mud.
20 - 27	Same; abundant gastropod and pelecypod shell fragments and intact pelecypod halves.
27 - 29	Gastropod layer.
29 - 30	Brownish-red algal mud.
30 - 43	Tan-colored algal mud; abundant gastropod and pelecypod shell fragments and whole large gastropods.
43 - 49	Yellowish-brown algal mud.
49 - 58	Light-tan-colored algal mud; abundant sand-size gastropod and pelecypod shell fragments; green algal layer at 52 cm.
58 - 69	Intact pelecypod halves and large gastropods in tan-colored algal mud matrix.
69 - 79	Tan-colored mud; not algal.
79 - 82	Pelecypod and gastropod shell fragment sand.

Table 4. Megascopic description of sediments in Core 27a-1.

Depth (cm)	Description
0 - 6	Sand-size and silt-size gastropod and pelecypod shell fragments partially cemented together with calcium carbonate; occasional benthic foraminifera.
6 - 63	Same; abundant rounded beachrock pebbles with exterior black algal coating.
63 - 120	White calcium carbonate mud with occasional aeolian pebbles.

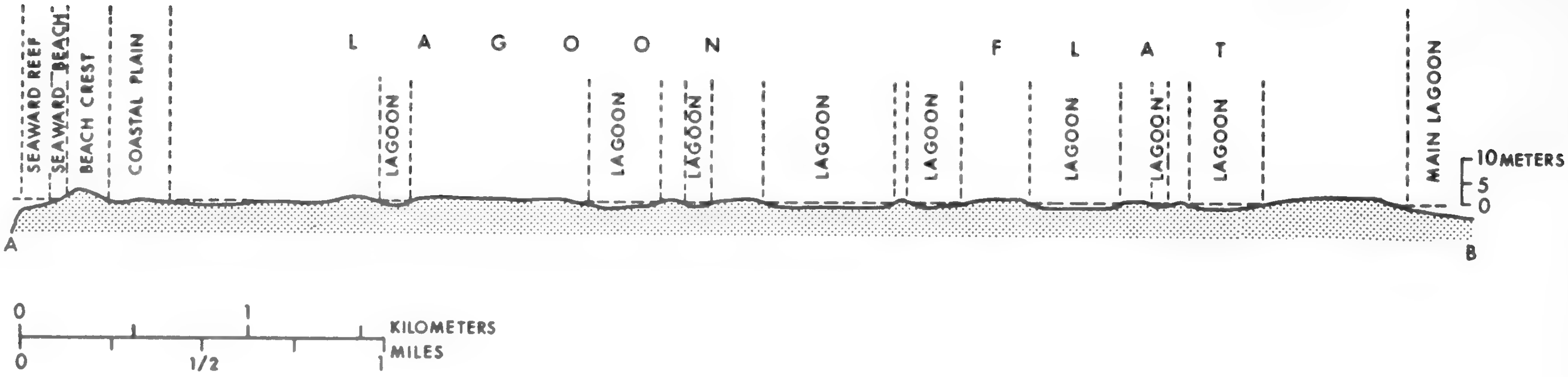


Figure 3. Representative topographic cross-section including the geomorphologic zones outlined in Table 1 (from Jenkin and Foale, 1968).

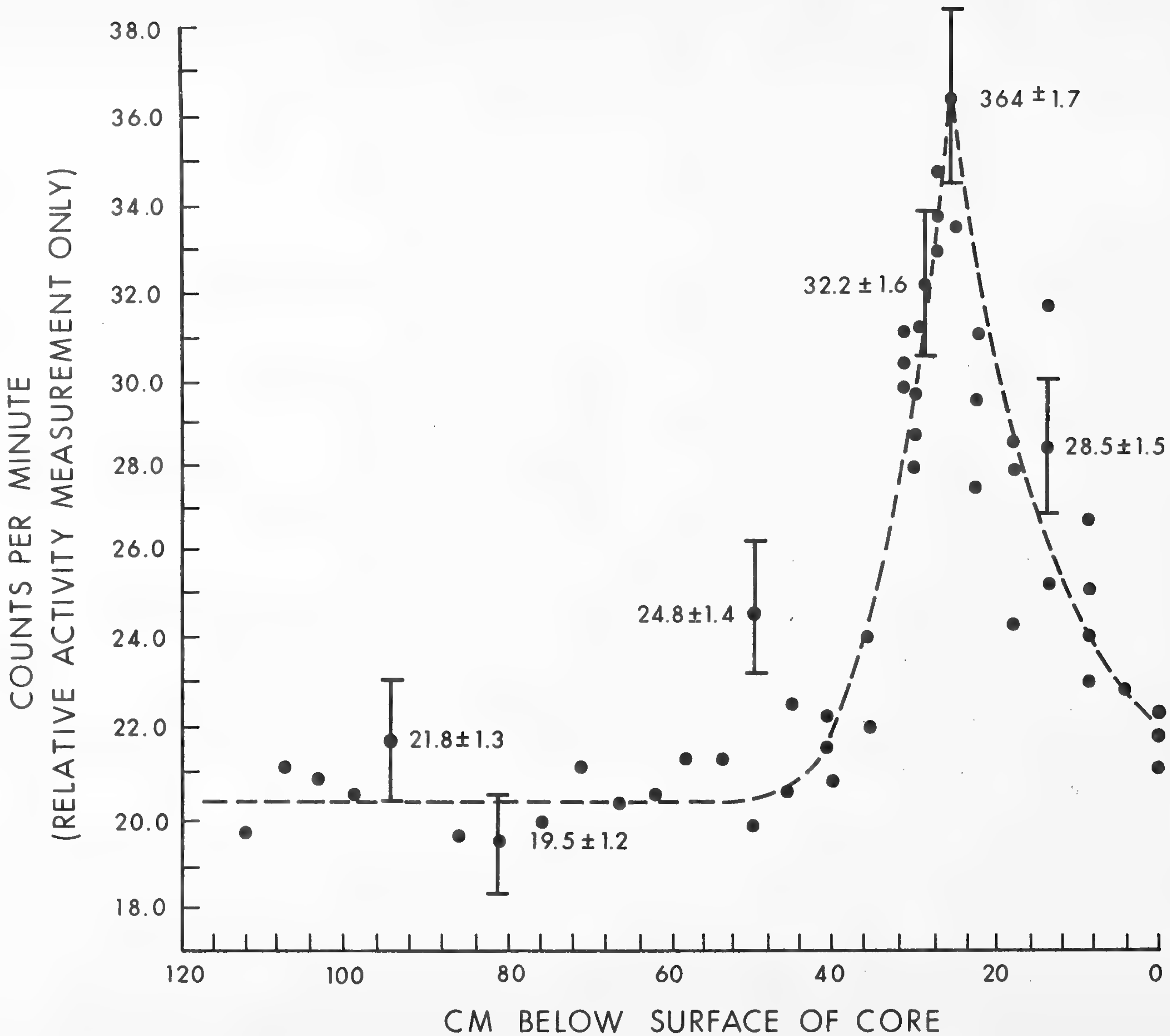


Figure 4. Graph of radioactivity of Core 27a with depth. Bars represent ± 1 standard deviation for selected points. All counting intervals were the same, so equivalent rates have the same standard deviation. The slight deviation from a step function is due to resolution limitations of the 5-7.5 cm-wide detectors; for example, the maximum activity at 28 cm is still detectable at 32 cm. The graph is consistent with a single event and no post-depositional sediment disturbance (after D. Knutsen and R. Buddemeir, unpublished data).

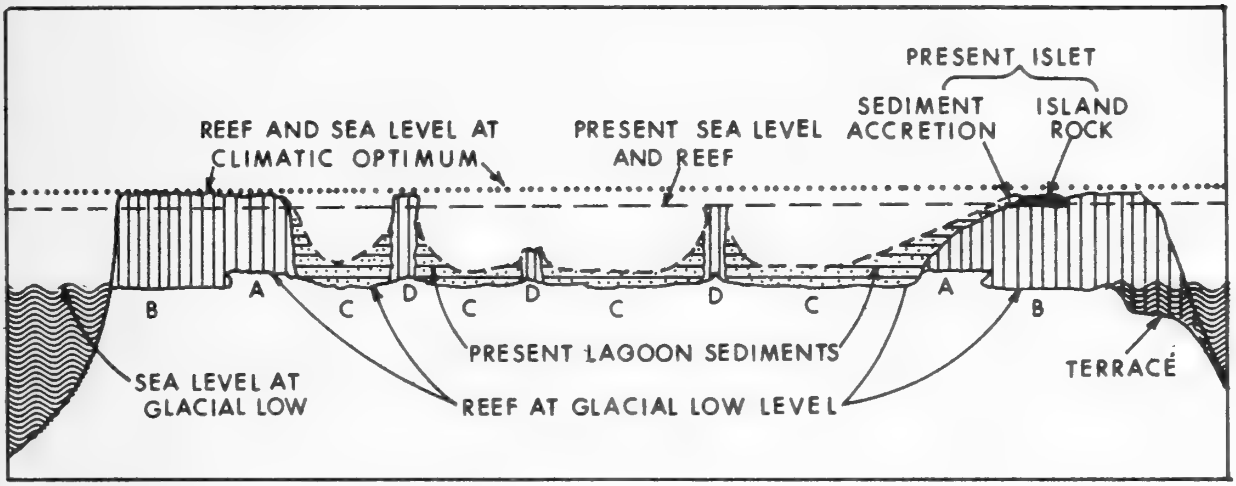


Figure 5. Hypothetical diagram of atoll evolution. A, undercut "raised" reef remnant; B, old reef flat; C, old lagoon bottoms; D, coral patches, knolls, or pinnacles. (From Wiens, 1962, Figure 40.)

ATOLL RESEARCH BULLETIN

NO. 198.

NOTES ON THE VERTEBRATE FAUNA OF TONGAREVA ATOLL

by Roger B. Clapp

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

NOTES ON THE VERTEBRATE FAUNA OF TONGAREVA ATOLL

by

Roger B. Clapp[1]

Tongareva (or Penrhyn) Atoll, at 9° S, 158° W in the south central Pacific Ocean, is the northernmost of an isolated group of islands north of the Cook Islands, and like them is administered by New Zealand. Tongareva is a typical ring atoll about 40 miles in circumference and contains a lagoon of about 108 square miles (Buck, 1932).

The vertebrate fauna of the atoll has been little studied despite relatively frequently visits by missionaries, anthropologists, and zoologists. The atoll was visited by the Kaimaloa Expedition in December 1924 and in September 1936 and April 1937 by William F. Coultas and R.W. Smith, respectively. Both Coultas and Smith collected birds but no formal reports on the collections were ever written.

On 13 June 1965, Tongareva was visited for 9 hours by a survey team of the Smithsonian Institution's Pacific Ocean Biological Survey Program (POBSP). Only the "bird islets" including Vaiari Islet at the southwestern corner of the lagoon and portions of the northwestern rim were visited.

Recently Batham and Batham (1973) presented observations on the birds of the atoll made during a visit from 12 August to 20 September 1968. The present paper presents additional information on the vertebrates of Tongareva Atoll and comments on Batham and Batham's useful contribution. Appendix Table 1 lists bird specimens collected in 1936, 1937 and 1965.

---

1 National Fish and Wildlife Laboratory, U.S. Fish & Wildlife Service, National Museum of Natural History, Washington, D.C. 20560
(Manuscript received February 1975 -- Eds.)

Mammals

At the time of the POBSP visit, cats (*Felis domestica*), dogs (*Canis familiaris*), and pigs (*Sus scrofa*) were being raised by the natives. Comments in Ward (1967) and by Lamont (1867) suggest that the pigs may have been introduced to Tongareva in 1853 from the shipwrecked vessel Chatham. Rats (*Rattus* sp.) were numerous in 1965, but as no specimens were collected their identity is unknown. Lamont (1867) stated that in 1853 "... [the natives] had never seen an animal larger than a very small rat, that lives principally in the cocoa-nut trees ...." Lamont's description suggests that the rats on Tongareva are *Rattus elegans*, a species widely distributed on the Pacific Islands.

Reptiles

Although native informants indicated that turtles (most likely the Green Turtle [*Chelonia mydas*]) were frequently caught at Tongareva no turtles were observed during the POBSP visit. Lamont (1867) and Buck (1932) indicate that turtles were caught by the natives for food.

Burt and Burt (1932) in their report on the herpetological results of the Whitney Expedition stated that the collections of the American Museum of Natural History contained one specimen of the Mourning Gecko (*Lepidodactylus lugubris*, AMNH 41749) and one of the Blue-tailed Skink (*Emoia cyanura*, AMNH 41748). They also indicated that E.H. Bryan, Jr., had collected these specimens while a guest of the Whitney South Sea Expedition in 1925. In fact, these specimens were collected by the Kaimaloa Expedition in 1924 (E.H. Bryan, Jr., *in litt.*) and mentioned by Gregory (1925). Ball (ms.) added that the single example of Mourning Gecko seen was collected and that the skinks were common but difficult to capture.

More recently the POBSP collected 28 specimens of four species of lizards. The more abundant species, the Mourning Gecko (14 specimens, USNM 158325-338) and the Blue-tailed Skink (10 specimens, USNM 158340-349) were those reported by Burt and Burt. The other two species collected were the Snake-eyed Skink (*Cryptoblepharus boutoni*, 1 specimen, USNM 158339) and the Polynesian Gecko (*Gehyra oceanica*, 3 specimens, USNM 158322-324). Both of the latter species were widespread on well vegetated central Pacific atolls but neither has been recorded previously from Tongareva.

Birds

Annotated List

In the following species accounts the presence of brackets about the name of a bird indicates that the occurrence of the species on

Tongareva is not well documented and that its occurrence there should be considered hypothetical

[White-tailed Tropicbird *Phaethon lepturus*]

Native informants indicated that this species is rarely seen at Tongareva.

Red-tailed Tropicbird *Phaethon rubricauda*

About half a dozen birds were seen by the Bathams, but no definite evidence of nesting was obtained by them. One bird seen under a bush may have been in the pre-laying stage.

Brown Booby *Sula leucogaster*

The Bathams found a bird incubating two eggs; this is the only record of nesting for this species on Tongareva. The only other record of occurrence is that of a Brown Booby banded on Jarvis Island, 30 May 1940 and recovered at Tongareva on 15 February 1941 (Munro 1944).

Red-footed Booby *Sula sula*

These birds were seen and collected in 1936, 1937, and 1965. All three of the POBSP specimens were collected from a group of ten birds seen on the southwestern bird islets. No evidence of nesting was found.

Two Red-footed Boobies banded elsewhere were recovered at Tongareva. One was banded 9 August 1938 on Jarvis Island by George C. Munro and recaptured at Tongareva on 28 February 1941 (Bryan, 1970). Another banded as a nestling 24 June 1965 on Malden Island by the POBSP, was recovered at Tongareva on 15 June 1966.

Great Frigatebird *Fregata minor*

This species, like the Red-footed Booby, was seen and collected in 1936, 1937, and 1965 but was not recorded by the Bathams. There is no evidence that the species breeds on Tongareva. Munro (1960) reported a Great Frigatebird that had been banded on Enderbury Island of the Phoenix Islands and recovered on Tongareva.

Lesser Frigatebird *Fregata ariel*

Large immature young were recorded by the Bathams during their visit, and approximately 150 birds were seen on the southwestern islets during the visit by the POBSP. The POBSP personnel found about 10 nests with eggs and 2 with nestlings in nests 7-8 feet up in 10 to 12 foot high trees (*Pemphis acidulus*). Native informants indicated that the species formerly nested in much greater numbers.

The Bathams stated that natives told them that band recoveries of *Fregata* from Australia and the United States had been obtained at Tongareva. It seems very unlikely that there have been any band recoveries from Australia. The "recoveries from the United States" presumably refers to the Great Frigatebird recovery mentioned above.

Pintail *Anas acuta*

An adult female banded 16 August 1949 at Tule Lake, California, was shot 15 November 1949 at Tongareva. This is the only record of this species from Tongareva.

Domestic Fowl *Gallus gallus*

Chickens were being raised by the natives when the island was visited in June 1965. Probably these birds were first introduced to Tongareva in September 1853 (Ward, 1967; Lamont, 1867).

Golden Plover *Pluvialis dominica*

The POBSP saw six Golden Plovers along the west side of the island. The Bathams reported that this species was widespread on the atoll. They also stated that natives told them that this species and the Ruddy Turnstone nest on Tongareva but did not comment on this obviously erroneous information.

Bristle-thighed Curlew *Numenius tahitiensis*

The POBSP saw two of these curlews and collected one.

[Asiatic Whimbrel *Numenius phaeopus variegatus*]

This race of the Whimbrel, listed as *Numenius variegatus* by the Bathams, was stated by them to occur in small parties of two to nine on open areas of old bare coral. Although it is possible that this western Pacific species was seen, it seems much more likely that this record (and a similar record by the Bathams for Suvarov Atoll) were of the Bristle-thighed Curlew, which could be expected to occur on these atolls in some numbers.

Ruddy Turnstone *Arenaria interpres*

Turnstones have been recorded only by the Bathams, who found them on every islet visited.

Wandering Tattler *Heteroscelus incanus*

Wandering Tattlers were first recorded by the Kaimaloa Expedition in 1924 when a few were seen (Gregory, 1925). Subsequently six specimens were collected in April 1937 by Smith, and three were recorded along the west side of the atoll during the POBSP visit in June 1965.

[Black-naped Tern *Sterna sumatrana*]

Native informants indicated that this species is rarely seen at Tongareva.

Sooty Tern *Sterna fuscata*

Three birds were seen offshore in December 1924 and about 40 were seen flying over the island by the POBSP. The Bathams received six eggs which were attributed to this species, but further documentation of the nesting of this species on Tongareva would be desirable.

Blue-gray Noddy *Procelsterna cerulea*

A nestling preserved in spirits at the American Museum of Natural History is the only record of this species from Tongareva. The bird was collected 26 September 1936 by Coultas.

Brown Noddy *Anous stolidus*

Ball (ms.) first recorded these birds on the atoll in December 1924 when they were incubating eggs in nests in the coconut trees. Brown Noddies were commonly seen when Tongareva was visited by the Bathams. Nests with young and one with an egg were seen. Only two large nestlings were found during the visit by the POBSP. Both were in nests in *Pandanus* trees. In all, an estimated 300 birds were seen during the June 1965 visit, about 100 along the southwestern islets and the rest along the northwestern portion of the atoll.

Black Noddy *Anous tenuirostris*

These birds were the most abundant seabird on the atoll when it was visited by the POBSP. An estimated 3,000 birds were seen on the small islets at the southwestern corner of the lagoon. At this time between 1,000 and 1,200 nests were present but birds were associated with only about 150 and all these contained eggs. Nests were primarily constructed of leaves of *Pandanus* and grass (*Lepturus* sp.) and were located in *Pandanus* and *Tournefortia* trees. Later in the season (of a different year), the Bathams found both eggs and nestlings, some in *Pandanus* and a few others in *Pisonia grandis*.

White Tern *Gygis alba*

These terns were fairly abundant when the island was visited by the POBSP. Sixty-five counted among the islets at the southwestern corner of the atoll, and another seven were counted at the northwestern corner. No nests were found during the POBSP visit, but gonad data from the four specimens collected suggest that the birds were breeding in June 1965. Both eggs and young were found by the Bathams in August-September 1968.

Populations evidently decrease considerably during the northern hemisphere winter as only a few of these terns were seen by the Kaimaloa Expedition in December 1924 (Gregory, 1925). During this visit, Ball (ms.) considered the species uncommon.

[New Zealand Cuckoo Eudynamis taitensis]

The Bathams reported a bird that the natives called "Koekoea", which was purportedly this species, but did not see one. The occurrence of the New Zealand Cuckoo on this atoll should be watched for.

Summary

This paper briefly summarizes what is known of the vertebrate fauna of Tongareva Atoll. Four species of mammals, dog, cat, pig, and an unidentified rat (*Rattus* sp.), occur on the atoll as does an unidentified turtle, probably *Chelonia mydas*. Four species of lizards, all of wide distribution in the central Pacific, are present. Two of these, the Snake-eyed Skink and Polynesian Gecko, are reported from the atoll for the first time.

Excluding species of hypothetical occurrence 16 species of birds are known from the atoll. Of these, the Brown Booby, Lesser Frigatebird, Brown, Black, and Blue-gray Noddies and White Tern are seabirds that breed or have bred on the atoll. Four other species of seabirds, Red-tailed Tropicbird, Red-footed Booby, Great Frigatebird, and Sooty Tern, visit the island regularly. The Red-tailed Tropicbird and Sooty Tern may breed on Tongareva.

The remaining six species include four migrant shorebirds, the Golden Plover, Bristle-thighed Curlew, Ruddy Turnstone, and Wandering Tattler, a vagrant duck (the Pintail), and the introduced Domestic Fowl.

Acknowledgements

I am indebted to the members of the POBSP survey team, Fred C. Sibley, Robert R. Fleet, Lawrence N. Huber, C. Robert Long, Dennis L. Stadel, and Robert S. Standen, upon whose field work this report is based. I also thank M. Ralph Browning, John S. Weske, Marshall A. Howe, and Philip S. Humphrey who read and commented on the manuscript. This is paper number 110 of the Smithsonian Pacific Ocean Biological Survey Program.

References

Ball, S.C. (ms.1924) *Field notes taken while on the Kaimaloa Expedition* . Original in the B.P. Bishop Museum, Honolulu.

Batham, J. and A. Batham. 1973. Field notes on birds observed on the 'motus' of two atolls (Penrhyn and Suwarrow) in the northern Cook Islands, 1968. *Notornis* 20: 97-101.

Bryan, E.H., Jr. 1970. History of bird banding in Hawaii. 2. Review of articles in the Elepaio. *Elepaio* 30(11): 100-103

Buck, P. 1932. Ethnology of Tongareva. *B.P. Bishop Mus. Bull.* 92: 1-225.

Burt, C.E. and M.D. Burt. 1932. Herpetological results of the Whitney south sea expedition. VI. Pacific island amphibians and reptiles in the collections of the American Museum of Natural History. *Bull. Amer. Mus. Nat. Hist.* 63: 461-597.

Gregory, H.E. 1925. Report of the Director for 1924. *B.P. Bishop Mus. Bull.* 21: 1-55.

Lamont, E.H. 1867. *Wild life among the Pacific Islanders.* London, Hurst and Blackett.

Munro, G.C. 1944. Notes on migration and straggling birds. *Elepaio* 4(6): 33-34.

Munro, G.C. 1960. *Birds of Hawaii,* revised ed. Rutland, Vermont, Charles E. Tuttle Co.

Ward, R.G. (ed.) 1967. *American activities in the central Pacific 1790-1870.* vol. 3, Ridgewood, N.J., Gregg Press.

Appendix Table 1: Bird Specimens Collected on Tongareva Atoll

Species	Sex	Museum Numbers (USNM) Of Birds Collected 13 June 1965 by the POBSP	Museum Numbers (AMNH) of Birds Collected 22-26 September 1936 by William F. Coultas	Museum Numbers (PAS) of Birds Collected 28 April 1937 by R.W. Smith	Totals
Sula sula		495698	336391-392	128691	4
		495699-700		128692-693	4
Fregata minor		495716	336393	128725	3
			336394-395		2
Fregata ariel		495704	336397, 336399		3
		495705	336398		2
Numenius tahitiensis		495732			1
Heteroscelus incanus				128524, 128548-551	5
				128547	1
Sterna fuscata		495472, 495475	336411	128532-534	6
		495473, 495474	336412		2
Procelsterna cerulea			336413		1
Anous stolidus		495552-558		128588-589	9
		495559-560	336401-402		4
Anous tenuirostris		495577, 495579	336403	128602-604	6
		495578	336404		2
Gygis alba		495602	336410		2
		495599-601			3
					60

ATOLL RESEARCH BULLETIN

NO. 199.

OBSERVATIONS ON VEGETATION OF BLUE-FACED BOOBY COLONIES ON COSMOLEDO ATOLL, WESTERN INDIAN OCEAN

by Mary E. Gillham

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

OBSERVATIONS ON VEGETATION OF BLUE-FACED BOOBY COLONIES ON COSMOLEDO ATOLL, WESTERN INDIAN OCEAN

by

Mary E. Gillham[1]

Localities occupied by boobies on Wizard and Pagoda Islands

Cosmoledo Atoll lies approximately 960 km east of the Keny coast in latitude 9°40' S. It consists of a circle of islands around a 8 km wide lagoon and spans some 14.5 km by 11 km. Like Aldabra, which is about 160 km nearer to the African mainland, it consists of an old, uplifted coral reef, but it is less rugged, much of the rock surface being hidden under drifts of coral sand. Wizard Island or Grande Ile is one of the half dozen or so larger islands, second in size only to Menai Island where the only settlement is situated. It is 3 km long and forms part of the eastern rim of the atoll, rising some 3.6-4.6 m above sea level.

It was possible to visit only the southern part of this island when the *Manihine* called there in February 1970. Much of this part is scrub covered, so that the ground-nesting Blue-faced or Masked Boobies (*Sula dactylatra*) are uncommon, but nests were scattered along the straggling corridors of low heraceous vegetation between the shrubs.

Some of the coastal bushes were occupied by Red-footed Boobies (*Sula sula*) and some of the inland ones by Lesser Egrets (*Egretta garzetta*) and Cattle Egrets (*Bubulcus ibis*).

Pagoda Island is representative of the many smaller islets occuring on the atoll rim. It is perhaps 0.4 km long and less wide, and, being more exposed to the influence of the sea, supports few shrubs of any size. Many of these lie below the general ground level around the rugged margins of a saline pond sunk in the champignon behind the storm beach on the ocean side, and having only subterranean connections with the sea.

The falling tide leaves curtains of filamentous algae draped about the lagoon walls. Vegetation crowning the storm beach is limited by salty winds to low growths such as the tight wiry rosettes of the sedge,

---

[1] Extra Mural Department, University College of South Wales, Cardiff
(Revised manuscript received September 1974 --Eds.)

Fimbristylis species, in contrast to the tall *Cyperus ligularis* and shrubs of coasts facing in towards the atoll centre.

Bushes on Pagoda Island contained occupied nests of Red-footed Boobies in mid-February 1970; the low vegetation of the remainder of the island was sprinkled throughout with those of Blue-faced Boobies.

This islet is too exposed for mangroves and other trees of large size and the Red-footed Boobies were nesting chiefly on, rather than in, the fringe of low, windtrimmed *Pemphis acidula* bushes of the periphery and the even lower growths around the inland lagoon.

On Wizard Island, where the range of nest sites is larger, they were favouring the white mangrove (*Avicennia marina*), a species which is used little if at all on Aldabra, where it gorws in abundance but where *Rhizophora mucronata, Bruguiera gymnorrhiza* and *Ceriops tagal* seem to be preferred. Other trees such as the scarlet-flowered *Cordia subcordata* are also used on Wizard Island.

<u>Other localities occupied in this sector of the Indian Ocean</u>

The status of Blue-faced Boobies on the rest of Cosmoledo is not completely known. Bourne (1966) records "A few seen on Cosmoledo and Assumption", giving no details as to which islands. Diamond (in Bayne et al 1970: 48) says "At least 200 pairs of White Booby *S. dactylatra* were occupying clearings in the long grass on the west side of the island (Wizard) or on the dune ridge to the east" in March 1968. Vesey-Fitzgerald (1941) records them as breeding in September-November 1940 on four of the Cosmoledo Islands (West North, East North, Grande Polyte and South) but does not mention Wizard or Pagoda. Piggott (1961) saw large numbers of boobies, species unstated, on Grand Polyte and also bird colonies on Pagoda and South Island.

Aldabra in the same latitude and only approximately 760 km from the African mainland, is an important sea bird resting site, but Blue-faced Boobies are not among them. Up to 1966 (Benson, 1966) the only evidence for their occurrence, even as non-breeders, is from Morris (1963), who saw both adult and immature birds. Red-footed Boobies, on the other hand, are abundant in the mangroves, many thousands nesting among the frigate birds (*Fregata minor* and *F. ariel*) on Middle Island. The absence of the ground-nesting species is surprising in view of the open platin and grassed areas which would seem eminently suitable.

Assumption, 40 km to the south of Aldabra, supporting a few breeding Blue-faced Boobies in the late nineteenth century (Ridgeway, 1895; Nicoll, 1906) but as a result of guano-digging activities it is unlikely that any still survive (Stoddart et al 1970).

On a wider scale *Sula dactylatra* has isolated breeding sites along the coast of East Africa from the Red Sea to Tanzania, and on Socotra. Generally these are sited on rocky coats and cliffs 6-9 m above sea level (Mackworth-Praed and Grant, 1957). Those of Wizard Island and of

Latham Island (65 km off Dar-Es-Salaam and visited by the present author in January, 1970), however, are on quite smooth terrain, uninterrupted by cliffy out-crops and not more than about 3 m above sea level.

Early regeneration phase of vegetation: Wizard Island

The areas occupied by ground-nesting boobies on Wizard Island were limited to patches of open ground seldom more than 20 X 10 m among the overall cover of shrubs. These sites were scattered along the coasts, often to the top of the low coral 'cliffs', but usually separated from the reef by a belt of different vegetation. On and below the jumble of honeycombed champignon rocks of the coastline were thickets of brilliant-flowered *Cordia subcordata* and occasional large white mangroves (*Avicennia marina*) with more spherical bushes of *Xylocarpus granatum* loaded with big green 'cannon-ball' fruits. Where the shore was sandier these were replaced by lower, denser bushes of white-flowered *Pemphis acidula* and yellow-flowered *Suriana maritima,* both self-tolerant species, branching copiously from the base and with characteristically small, sclerophyllous leaves. In areas of mixed rock and sand were silvery-leaved shrubs of *Tournefortia argentia* with speckled orange and white moths massed on their large inflorescences.

Only a small proportion of the guano-impregnated soil of the booby nesting areas was bare in February 1970. Most, sometimes up to 90%. was covered by a flattened, straw-coloured mat of dead grass, probably *Dactyloctenium aegyptium.* On this the boobies laid their one or two eggs (usually white, but occasionally pale blue), more sparsely than on Latham Island at the same season. No nesting material was used, but a bare circle of approximately 60 cm diameter was scraped in the dead grass. This was not one of the peak laying periods and tentative plant colonisation had begun between nests in areas which the presence of guano and nest hollows showed to have been recently vacated.

The three pioneer plant species were annuals, growing radially from their points of origin to form neatly circular clumps up to 1 m across but to occasionally near 3 m by 13 February 1970. One of them, the succulent *Portulaca oleracea,* was also the principal species of the blue-faced colony on Latham Island, where vegetation was generally much scantier. The other two Wizard Island pioneers were less succulent and quite prostrate; the minute-leaved, green-flowered creeping spurge (*Euphorbia prostrata*) and the yellow-flowered, pinnate-leaved *Tribulus cistoides.* Fruits of this usually possess 5 carpels, with 2 large, upwardly directed prongs. Close after these 3 species came a creeping ground cover of *Boerhavia repens,* with umbels of tiny white or pink flowers protruding from a continuous carpet of dark, red-tinged leaves. Superimposed in places were the stems of an unidentified cucurbit with yellow flowers 2.5 cm across. The purple-flowered, green-podded herb, *Cleome strigosa* was locally abundant at this stage, principally as seedlings. Mature plants were more or less prostrate, in contrast to an average height of 50 cm in parts of Aldabra unaffected by birds.

Other components of this bird flora were the orange flowered, *Sida parvifolia;* the yellow-flowered *Portulaca* species; the yellow-flowered, trailing Composite, *Launaea sarmentosa;* the mauve-flowered sea Convolvulus (*Ipomoea pes-caprae*) and the grasses, *Dactyloctenium aegyptium,* with radiating flower spike and *Sporobolus virginicus,* with narrow, erect flower spikes.

Peripheral to these, on less recently disturbed ground, were low undershrubs of *Achyranthes aspera* with 30 cm long spikes of mauve flowers ripening from the bottom upwards and falling to leave reflexed bract scales. Seedlings of another small bush, *Acalypha claoxyloides,* sprouted between them, their soft, balsam-like leaves veined with yellow among lax catkins of minute yellow-green flowers.

This low and easily negotiable community of undershrubs alternated with the booby colonies, to form with them a coastal belt 7-10 m wide. There is every probability that this belt represented areas occupied at some time or other by boobies and showing an intermediate successional phase between a fully occupied herbaceous sward and an unoccupied scrub. Both species, *Achyranthes* and *Acalypha,* grew to 2 m in the main inland scrub, where, along with many other shrubs, such as the small-flowered, round-leaved *Pleurostelma cernuum* of the milkweed family (Asclepiadaceae), they became generously festooned with creepers. Chief of the lianas was the white-flowered morning glory (*Ipomoea macrantha*) and there was also a small, green-flowered passion fruit (*Passiflora suberosa*). The tall brown-headed sedge, (*Cyperus ligularis*) occupied sandy hollows.

Later regeneration phase of vegetation: Pagoda Island

Blue-faced Boobies, as indicated, occupied almost the entire area of Pagoda Island, but spacing of the nests was as wide as on Wizard (although it was difficult to be certain of this because many of the well-grown chicks were tucked under bushes and not visible unless flushed). The ground was of coral gravel further whitened by guano and with little sand. Not much was bare and there was little grass, the area being divided between a prostrate herb flora dominated by *Boerhavia repens* and a sapling shrub flora dominated by *Achyranthes aspera*.

On the open area the *Boerhavia* carpet formed a ground cover of about 60%; *Euphorbia prostrate* covered another 20%, whilst 10% was bare. The remaining 10% was occupied by two forms of *Tribulus,* principally a robust one with larger flowers and fruits than any seen on Wizard. With it were *Sida parvifolia, Portulaca oleracea, P. australis, Sesuvium portulacastrum* and a little *Launaea sarmentosa*.

Throughout this sward seedlings of *Achyranthes aspera* and *Acalypha claoxyloides* were growing, especially the former. The *Achyranthes* dominating the main part of the island obviously represented the same community in a more advanced successional phase, the herbaceous sward which persisted between the 30-100 cm high bushes diminishing until

these finally coalesced.

Apparently not involved in this 'booby succession' were the thick stands of *Plumbago aphylla* backing the rocky beaches and land-locked pond. Most of its grey-green stems were bare, but some patches retained the ephemeral circular leaves produced during the rains (December to March), and considerable stands on the ocean side bore massed white flowers — the plants reminiscent of a less succulent version of *Sarcostemma viminalis*. *Cyperus* was associated with the *Plumbago* in places.

The greater state of advancement of the booby plant succession on Pagoda is of particular interest when considered in relation to the more retarded climatic succession of this smaller, more wind-swept and spray-drenched island. Few bushes exceeded 1 m in height, there were no mangroves and no *Cordia* trees around the fringes and little variety of species in the main body of the island. Only one *Tournefortia argentia* bush was seen, its main trunk prostrate, living branching to only 60 cm and dead ones overtopping these by another 60 cm. *Pemphis acidula,* the only abundant shrub around the edge of the *Boerhavia-Achyranthes* succession, was generally gnarled and mis-shaped by the wind.

The greater growth of the post-booby vegetation could have been the result of either a sparser total population of boobies on an annual basis or an earlier start to nesting. Most chicks were 4-5 months ahead of those on Wizard Island and it is probable that, with this low bird density, vegetation grew up alongside them, affording useful cover as their parents left them unattended for longer periods. This cover may be of greater importance in giving protection from the sun's heat than from predators, midday temperatures in February reaching to 110 F on the Aldabra group of islands. (A comparable case is seen with the lesser black-backed gulls (*Larus fuscus*) in Britain where eggs and constantly brooded young chicks occur in open grassland, the bracken fronds sprouting as the chicks grow, so that they have ample cover during their vulnerable adolescence.)

The almost universal coverage of dead grass in the Wizard nesting areas shows that these do not follow quite the same successional sequence as the Pagoda ones. It seems that the grass invades before the seedling bushes become established, although the earlier herb phase of the two successions runs parallel. (Diamond's only reference to booby vegetation in March is to 'long grass' (Stoddart et al 1970: 49), but there was little sign of its regeneration in February 1970, so the sequence may not be the same each year.)

Predation and aggressiveness

Predation of boobies in the air over Wizard was serious, hundreds of Greater and Lesser Frigate-birds harrying them in flight. It was not possible to judge whether frigates selected their victims only from among birds returning with newly caught fish, but many boobies were

seen to regurgitate at the end of a noisy, squawking aerial chase. The food was invariably caught by one of the pursuing frigates as it fell. As many as 5 or 6 of these would join forces against a single booby in a spectacular pursuit from which the quarry's only escape was to alight, either on land or sea. (Frigates are clumsy on land and get waterlogged at sea, but are past masters of flight.)

More serious predation on Wizard was by cats. The booby colonies were thickly littered with cat droppings consisting almost entirely of booby feathers and down with, sometimes, a little fibrious plant material. A cat was seen, not resembling the expected feral animal of domestic origin, but larger, spotted and with a long tail, although how a wild cat could arrive on an uninhabited coral atoll remains a mystery.

Many adult boobies were on empty nests and, of the remainder, most had eggs. Only a few chicks were seen, none very large. Chicks would be very vulnerable to cats, and it is suggested that the regarded state of breeding as compared with the adjacent Pagoda Island, where no cat dung was seen, may be due to replacement-laying by robbed parents. It could be significant that surviving chicks had particularly aggressive parents, more likely to hold their ground in defence of young. (There was no indication on Latham Island that birds with chicks were more aggressive than birds with empty nests or eggs. This seemed to be an attribute of some individuals only, and on Wizard Island an attribute aiding race survival.) Wizard Island birds with no chicks tended to take to the air when approached to within 6 m. Those with chicks stood their ground, lunging at the intruder when handled. While chicks were very young the parent manages to maintain their positioning — one on top of each of the grey webbed feet — while swivelling round to face the disturbance and jab at outstretched hands, quite unintimidated.

Diamond (in Bayne et al., 1970) suggests that cats may be responsible for the partial or complete loss of terns from Wizard Island. He found only skeletons and feathers in long grass and on dune ridges. They clearly suffer heavy mortality, whether from predation, starvation or disease is not known; but the most likely culprits would seem to be the cats, of which 2 were seen and one shot (A. W. Diamond, personal communication). Baker (1963) refers to a tern breeding area at the north of Wizard Island, but none were seen in March 1968 nor February 1970.

Pagoda Island was occupied by advanced booby chicks progressing from the downy to the feathered stage and falling about awkwardly as they exercised their wings. Few were less than half grown and only 3 eggs were seen. These older chicks were left for longer periods unattended and were exceedingly noisy and aggressive. They started squawking when the intruder was still a long way off and when he passed within 2 m he was likely to receive a jab in the leg sufficient to draw blood.

As far as could be ascertained, there was no predation of boobies on Pagoda apart from food thieving by frigates, and this was less prevalent than on the larger island, only 40-50 frigates being seen.

Landings by man on so small an island surrounded by reef must be few.

Continuity of bird pressure on vegetation

The most depauperate, bird-suppressed vegetation seen by me in this part of the Indian Ocean in early 1970 was on Latham Island. Most of this area was currently occupied by breeding sea-birds in late January and it is likely that there is a fair continuity of bird pressure there, because all former records for terns and noddies have been from June-September, and for boobies from October-November and again in March (Mackworth-Praed and Grant, 1957). This, in conjunction with the prevalent salt-laden winds, precludes bush growth and limits the flowering plants to three low-growing herb species: *Portulaca oleracea, P. australis* and *Ipomoea pes-caprae*.

Local curtailment of bush growth on Wizard Island may be due to a similar sequence of nesting by different individuals on the same site. Even if only boobies are involved, it has been established that these have no regular annual cycle, in either the Indian Ocean or the Atlantic.

With an incubation period of 42-46 days (6½ weeks) and a fledging period of 120 days (17 weeks), it is likely that the oldest, still down fledglings on Wizard in February 1970 came from eggs laid in October, and the predominantly older, half-feathered fledglings on Pagoda Island from eggs laid in September. Eggs and younger chicks, which were almost exclusive to Wizard, could have been laid at any time between November and February.

The possibility of occupation of the same sites by terns or noddies at other seasons cannot be excluded. Both have been recorded breeding on Wizard, and the predominance of dense, creeper-covered bushes limits the amount of suitably open terrain. All the sites seen without bushes were occupied to a greater or lesser degree by boobies, but the whitening by guano on some of these was more than could be attributed to the present occupants alone. Only future visits to the atoll can establish such joint use of the open spaces.

Other breeding seabirds observed in the part of Wizard Island visited in February 1970 were Red-footed Boobies (*Sula sula*), scattered in small parties amongst the taller coastal bushes, with eggs and chicks at all stages, and considerable flocks of free-flying brown immatures. Several hundred Cattle Egrets (*Bubulcus ibis*) and Lesser Egrets (*Egretta garzetta*) (mostly of the white phase, with no pied intermediates such as occur on Aldabra) thronged in larger trees further inland, but were not examined to see if they were nesting.

Other Lesser Egrets fed on the reef with Grey Herons *Ardeola cinerea,* Crested Terns *Thalasseus bergii,* Crab Plovers *Dromas ardeola,* Great Sand Plovers *Charadrius leschenaultii,* Curlew Sandpiper *Erolia testacea,* Sanderling *Crocethia alba,* Whimbrel *Numenius phaeopus* and

Turnstones *Arenaria interpres*. Of the two species of frigate bird, the Greater were present in larger numbers.

Very abundant land birds were the Souimanga Sunbirds *Nectarinia sovimanga*, taking nectar particularly from the big scarlet flowers of *Cordia subcordata*, and the constantly chattering, streaky Madagascar grass warblers *Cisticola cherina*, making short, lark-like flights over the bushes and occasionally over the sea. These warblers were present on Pagoda Island, but not the sunbirds, which would have failed to find *Cordia* and the other flowering trees which they favoured in this more exposed habitat. There were probably 50-100 pairs of Red-footed Boobies nesting on Pagoda and some 20 Red-tailed Tropic birds (*Phaethon rubicauda*) indulging in what appeared to be complicated courtship flights over the island. One bird on a nest beneath a dense *Pemphis acidula* bush screeched and spread wings and body feathers menacingly when approached, yielding no ground. Two others had nests under thickets of *Plumbago aphylla*.

Several flocks of 20-30 Black-naped Terns *Sterna sumatrana* had taken up positions on the rocky shore to which they returned soon after flushing, as though they might have chicks concealed beneath the rocks, but no young or eggs were seen. A single flock of about 30 crested terns fed on one of the sandy beaches. The air was full of terns above the next island of the atoll, which was almost certainly a breeding area, but was unfortunately not visited. Other shore birds were Turnstones, some of these leaving the pebbly beaches to forage among the low *Boerhavia* and *Euphorbia* of the booby areas. These and various other waders also fed around the enclosed tidal pool behind the ocean storm beach.

The deep hollow in which the pool lay was partly filled with bushes thronged with Red-footed Boobies. Other slopes carried *Sesuvium portulacastrum* near water level (a characteristic halophyte of mangrove swamps elsewhere), leading up through stands of either *Plumbago* or *Cyperus* to the short *Boerhavia* turf of the Blue-faced Booby colony.

Little Green Herons *Butorides striatus* fed from shoreward rocks and Grey Herons perched in statuesque positions on the tops of bushes, waiting to move down to the reef to feed. The greater and lesser frigates never alighted and were presumably from the breeding colonies in Aldabra, which supply most of the Western Indian Ocean frigates.

The ecological niche normally occupied by scavenging gulls, crows or kites, was filled by crabs, both land crabs and hermit crabs, hordes of which were busy devouring regurgitated fish and the occasional dead bird. The land crabs lived in burrows as much as 20 cm in diamter in hollows of the champignon.

Postulated vegetation sequence in sea-bird colonies

Even on so small an island as Pagoda, the climatic climax vegetation consists of bushes sufficiently large to satisfy the breeding needs

of Red-footed Boobies. Close nesting by these causes the dying back of the branches and eventually the entire shrubs. Heavy pressure by Red-footed Boobies, therefore, could destroy the scrub and leave the way open for herb and sapling woody species — i.e. the sort of environment favoured by Blue-faced Boobies.

The protracted nature of the nesting season on Cosmoledo enables degenerating and regenerating plant successions to exist side by side, so that the vegetation fluctuates between a dead or living herb cover and a sapling cover up to 0.5 m high. With the low nesting densities obtaining in Feburary 1970, this state is likely to be maintained in the booby colonies. With increasing booby pressure, as on Latham Island, bareness could previal, to give the sort of habitat favoured (and induced or maintained) by terns and noddies.

These two smaller species nest sufficiently close together to inhibit all plant growth in their chosen area, but they do not necessarily return to the same site in successive years. If they move away the vegetation will return — first the herbs, then the saplings and finally a full scrub cover, if given long enough without further disturbance. This change, however, makes the terrain suitable once again for the booby species, which may expand into it from nearby colonies. Colonially nesting sea-birds inevitably modify the vegetation amongst which they nest, and this may be to their own disadvantage and the advantage of others.

The vegetative degeneration: regeneration cycle associated with nesting birds might thus be as follows:

Degeneration:

Mangroves and other trees	. . . Red-footed Boobies and egrets
Pemphis and other shrubs	. . . Red-footed Boobies and Tropic birds
Boerhavia and other herbs	. . . Blue-faced Boobies and Tropic birds
Bare Soil	. . . Terns and noddies.

Regeneration:

Herbs and grasses	. . . Terns, noddies and Blue-faced Boobies
Shrubs	. . . Red-footed Boobies
Trees	. . . Red-footed Boobies, egrets, heron, etc.

Comparison between Cosmoledo and Aldabra Atolls

Colonies of ground-nesting sea-birds are more extensive on the Cosmoledo Atoll than on Aldabra, where the main colonial nesters are frigate birds and tree-nesting boobies in the mangrove fringes. The tree nesters defaecate into the intertidal zone, and so have little or no effect on the land flora.

The only sea-birds on Aldabra which are sufficiently numerous to affect the terrestrial ecosystem are the noddies of the tiny mushroom

islets in the lagoon, and many of the islets are so small and low as to be devoid of macroscopic vegetation. Crested, Caspian, and Black-naped and White Terns, Red-tailed and White-tailed Tropic birds, Grey Herons, Little Egrets and Sacred Ibises, if not nesting so diffusely as to have very localised effects on plants, are tree nesters.

The situation is very different with Cosmoledo's most important colonial nesters, the Blue-faced Boobies. This species has an immediate and obvious effect on the vegetation in which they nest and have changed the face of the islands considerably. It does not nest on Aldabra.

Thus, although Aldabra supports an unparalleled example of relatively undisturbed native scrub, Cosmoledo shows in this respect a much more interesting and complex interaction between flora and fauna.

Cosmoledo's vegetation is 'spoiled' if looked at in purist terms, but it is spoiled mainly by natural causes. The fact that the plants which have taken over in the wake of the birds are also plants which take over after distrubance by man, detracts nothing from the naturalness of their origin.

Modification of natural vegetation by large colonies of nesting sea-birds cannot fail to be of interest biologically. Intense modification usually implies the accumulation of guano in sufficient quantities to be a commercially viable proposition to mining companies, so that the natural outcome of the association is destroyed. So long as any of the birds remain, however, they have an inevitable impact on the existing vegetation, and examples of such bird-dominated vegetation should be jealously guarded.

Colonial sea-birds in large numbers are all too rare in the Tropics. In the interests of scientific investigation, it is very desirable that these semi-exploited islands should be conserved while birds are still in residence and governing the competitive efficiency of tolerant plants species over intolerant ones.

The rim of the Aldabra Atoll affords an admirable control area to show uplifted reef vegetation in the absence of colonial birds, but its reef islets are scarcely adequate to show reef vegetation in their presence. Cosmoledo shows this on a big scale, and the double interest, botanical and ornithological, cannot but be a useful adjunct to our knowledge of the botanical alone.

Tropical sea-birds are so much rarer than temperate and arctic ones that there would seem to be a very strong case for conferring reserve status on selected islands of the Cosmoledo Group. These would be ideal sites for instituting long term investigations on the delicately fluctuating balance between changing numbers of sea-birds and vegetation types having different levels of tolerance of trampling and guano deposition.

Acknowledgements

I am much indebted to Mr. Basil Bell, formerly Director, of E. A. M. F. R. O., and Mr. Mike Williams, Captain of the 'Manihine', for sea passage to Cosmoledo, and to Dr. J. B. Gillett, Dr. Brian Harris and Mr. Jack Frazier for the identification of plants.

Appendix

List of plants in and beside Blue-faced Booby colonies on Cosmoledo

Acalypha claoxyloides
Achyranthes aspera
Avicennia marina
Azima tetracantha
Boerhavia repens (?)
Cassytha filiformis
Cleome strigosa
Cordia subcordata
(Curcurbitaceae)
Euphorbia prostrata
Ipomoea pes-caprae
I. macrantha
Lagrezia sarmentosa
Launaea sarmentosa
Passiflora suberosa
Pemphis acidula
Pleurostelma cernuum
Plumbago aphylla
Portulaca oleracea
P. australis
Sçaevola taccada
Sesuvium portulacastrum
Sida parvifolia
Suriana maritima
Tournefortia argentea
Tribulus cistoides
Xylocarpus granatum
Dactyloctenium aegyptium
Eragrostis eiparia(?)
Fimbristylis cymosa(?)
Cyperus ligularis
Sporobolus virginicus

References

Bayne, C. J., Cogan, B. H., Diamond, A. W., Frazier, J., Grubb, P., Hutson, A., Poore, M. E. D., Stoddart, D. R. and Taylor, J. D. 1970. Georgraphy and ecology of Cosmoledo Atoll. *Atoll Res. Bull.* 136: 37-56.

Bourne, W. R. P. 1966. Observations on islands in the Indian Ocean. *Sea Swallow,* 18: 4¼-43.

Dorward, D. F. 1962. Comparative biology of the white booby and the brown booby (*Sula* spp.) at Ascension. *Ibis,* 103b: 174-220.

Mackworth-Praed, C. W., and Grant, C. H. B. 1957. *Birds of East and North East Africa.* 1: Longmans.

Piggott, C. J. 1961. *A report on a visit to the outer islands between October and November]960.* Directorate of overseas surveys, Land Resources Div. Typescript 1-71. Chap. 6 Cosmoledo. 27-30.

ATOLL RESEARCH BULLETIN

NO. 200.

VEGETATION OF SEA AND SHORE-BIRD COLONIES ON ALDABRA ATOLL

by Mary E. Gillham

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

VEGETATION OF SEA AND SHORE-BIRD COLONIES ON ALDABRA ATOLL

by

Mary E. Gillham[1]

Introduction

The present study was carried out during the early months of 1970 on Aldabra Atoll 640 km from the East African coast and 420 km north-west of Madagascar in lat. 9°24' S, long. 46°20' E.

Ground nesting sea-birds are found almost exclusively on the smaller islets in the 34 km long lagoon - easily accessible to man (who seems scarcely to have bothered them) but not to his predatory followers, the feral cats and rats. On the main island fringing the lagoon the birds, principally frigate birds and boobies, are tree nesters in the mangrove fringes, to which overland access is difficult.

Being mostly colonial nesters, sea-birds can have a profound effect on the vegetation amongst which they live, particularly in hot dry climates where corrosive guano remains largely undiluted. Compared with other sites investigated in three continents, both temperate and tropical and even as close as Cosmoledo Atoll, about 160 km to the east, these interactions between birds and plants on Aldabra are usually slight. Noddies (*Anous stolidus*) are the only birds which can be said to initiate any profound changes in the vegetation cover. The negligible influence of the rest is thought to be principally due to the dissipation of the guano, which either falls directly into the lagoon water or seeps away through the honeycomb structure of the champignon or uplifted reef rock.

On the neighbouring islands where guano accumulated (and no doubt had an important bearing on the vegetation type in so doing) this has been mined, destroying almost all the original plant life so that these effects cannot be observed. The very fact which saved the flora of Aldabra from similar destruction at the hands of man thus prevents a full investigation of plant/sea-bird relationships in this unique type of environment.

---

1 Department of Extra Mural Studies, University College, Cardiff
(Revised manuscript received September 1974 --Eds.)

Much the greatest effect of colonially nesting birds on plants is chemical, except perhaps in cool moist climates where precipitation greatly exceeds evaporation. Even there the chemical effect may be considerable, though beneficial rather than deleterious, the diluted excrement acting as a fertiliser (phosphatic and nitrogenous) instead of a too powerful toxin and plasmolysing agent which causes root hairs to shrivel and leaf tissues to 'scorch'.

Another type of chemical inhibition of plants by birds has been reported on certain islands further north towards the Seychelles Group where sooty terns (*Sterna fuscata*) are said to hover over the massed Madagascar periwinkles (*Catharanthus roseus*) and sprinkle them with salt water carried on their wings, so that they die (Beamish, 1970a). That this is a motivated activity is highly unlikely, the periwinkle having a normal growth height of 30 - 60 cm, with large soft leaves and flowers of a morphological form highly unsuited to survive even light bird pressure and certainly not the activities of a thriving colony of terns, whose nests are seldom more than 30 - 40 cm apart. Such bird normally hover over a nest site for long periods before finally settling in for laying.

Tree nesters

White Terns (*Gygis alba*)

These normally balance their single egg on the branch of a mangrove — *Rhizophora mucronata, Bruguiera gymnorrhiza, Ceriops tagal* or *Avicennia marina* — among undamaged foliage and are much too sparse on Aldabra to have any noticeable effect. Adults perch on dead *Pemphis acidula* twigs too fragile for egg supports, but this is no indication that they have killed the twigs. It would be interesting to know whether the much larger numbers on Cousin Island in the Seychelles, where fairy terns are said to nest commonly in coconut palms and Casuarina trees (Penny, 1970), have any local deleterious influence on these.

Frigate birds (*Fregata minor* and *Fregata ariel*)

Although nesting in bushes in some parts of their range, frigate bird occupy taller trees on Aldabra, Lesser Frigates often in the lower branches, Great Frigates (with a 7 ft. wingspan) higher up. Usually it is the various types of mangroves which are used for nesting, but others are occasionally used for perching, e.g. *Casuarina equisetifolia* and *Cordia subcordata*. Nests are fairly well scattered among the mangrove foliage, whose glossy leaves take little harm from coatings of white metabolite. They usually overhang the water of the lagoon. Few species of ground plant occur beneath nests and these but rarely. Most, like *Plumbago aphylla,* have few or no leaves to take harm.

Frigate birds tend often to roost communally and here their influence seems more potent. Trees used extensively are mostly dead, with the lesser twigs missing, possibly removed for nesting material.

Because these trees are generally in strategic sites, at channel junctions, on mid creek islands or the ends of promontaries, it is likely that they are chosen for their position rather than that they have already been killed by other means, and that their death is secondary and due to the birds. If so, this bears a close parallel with the many trees killed by cormorants (Phalacrocoridae), particularly in the Southern Hemisphere where this group is most numerous. Further evidnce of tree death as effect rather than cause of perching is evinced in local death of utilised branch tips. Upstanding 'elbows' frequented by birds suffer defoliation while leaves continue to persist on their pendant tips, proving that the leafless portions are still sufficiently alive to convey water and solutes.

Sacred Ibis (*Threskiornis aethiopicus*)

This species was not observed nesting during the February to May period spent on Aldabra, but Beamish (1970b) refers to "a series of untidy nests making an almost continuous platform 12 ft. above the ground" is Takamaka grove, an isolated woodland in the SE.

Tree and bush nesters

Red-footed Boobies (*Sula sula*)

What has been said of nesting frigate birds applies equally to these arboreal boobies which build in leafy mangroves. Dead trees for perching are, however, the exception rather than the rule, possibly because the boobies usually fly out to sea for their fish eating expeditions and do not need commanding lookout posts from which to spot likely quarry to be chased and robbed as the frigates do.

Seldom on Aldabra, where big trees are abundant, do Red-footed Boobies nest in bushes, as they do on Pagoda Island, Cosmoledo Atoll, in the absence of tall trees. On Wizard Island, Cosmoledo, both trees and bushes are utilised, the most favoured tree *Avicennia marina* and the most favoured bush *Pemphis acidula* (*Avicennia* is not a common tree in the Aldabra colonies and Diamond (1971) states that boobies do not use it for nesting).

Pemphis is usually set slightly further back from the shore than are the various mangroves so that excrement falls onto the ground rather than onto water or intertidal stretches of sand or reef. The density of the *Pemphis* bushes, in spite of local killing around the nests, is often too great, however, for any understorey of vegetation to grow beneath them. Falling guano can affect only the *Pemphis*. In fact, it is probable that little does.

If bushes are sited on champignon, it is likely that roots penetrate deep into crevices; if they are rooted in dry sand or chippings of reef rock, it is likely that the non-liquid guano is held up on the surface. Rain, when it falls, is usually torrential, so would wash this off the surface onto the beach or dilute it to a greater extent

than do the gentler rains of less tropical regions. But no doubt some of the nutriant salts do move downwards past the *Pemphis* roots during rain and rise past them again by capillarity during evaporation of ground moisture in dry spells — particularly in the sandier substrata.

Apart from local killing and twig plucking, it is not easy to ascribe any deleterious or beneficial changes to booby activity. Ground-nesting Blue-faced or Masked boobies (*Sula dactylatra*) which have such a profound influence on the vegetation of parts of the Cosmoledo Group, do not nest on Aldabra, in spite of suitable sites devoid of scrub on platin rock surfaces and tortoise-grazed turf.

Tree, bush and ground nesters

Grey Herons (*Ardea cinerea*)

Like the British subspecies of grey heron, which nests as readily on the bare rock of Scottish island cliffs as on the tall trees of English woodlands, the Aldabran herons will accept almost any type of breeding site.

Some build in trees, some in bushes and some on the ground. Nests are widely spaced and, although a dozen or more pairs may breed simultaneously on a small islet of some 20 X 40 m, they seem to be less colonial on Aldabra than in much of their range — possibly because of the long drawn out breeding season — all stages of building, eggs, chicks and fully feathered juveniles being observed during the February to May period 1970, with no synchronisation of laying as with the frigates and, to a lesser extent, the boobies.

The fact that most of the treenesting birds seen were in mangroves of one sort or another, reflects only the fact that mangroves are the commonest trees in the areas visited. The same can be said of the *Pemphis acidula* favoured by the bush breeders. Nests are in, rather than on these, being normally too bulkly to be supported by the uppermost twigs. Such sites provide cover for the gawky youngsters as well as opportunity for acrobatics.

Fairly obviously as a result of the heron activity many of the *Pemphis* bushes are dead, some collapsed into a heap of branches so that the nests are virtually at ground level and the material of which they are composed scarcely distinguishable from that of the supporting plants. Such nests are reminiscent of those of ospreys (*Pandion haliaetus*) on *Nitraria schoberi* bushes in Western Australia and those of crowned cormorants (*Microcarbo coronata*) on a variety of bushes on South African islands where, the host shrubs killed, both ospreys and cormorants continue to build up the level with annual increments of twigs to create artificial bushes for themselves (Gillham, 1961, 1963b). Material added to the Aldabra herons' nests in successive years was not seen to reach such substantial heights as these.

Around the herons' nests is a fairly thriving growth of *Achyranthes aspera*, occupying on average some 45% of the area and reaching to 120 cm high, evidently stimulated by the diffusing guano. Tufts of the following herbs occur in clearings: *Portulaca oleracea* (20%); *Sclerodactylon macrostachyum* (15%); *Cleome strigosa* (4%); *Corchorus aestuans* (4%); *Boerhavis elegans* (1%); *Dactyloctenium aegyptium* (1%); with 10% of the rock surface bare.

The *Pemphis* generally and the occasional *Ceriops tagal* mangrove are in poor shape — the whole illustrating a degenerative phase of a vegetative cover reverting from shrubs through semi-shrubs and herbs to bare rock.

Nests built deliberately on the ground are seldom in the open but placed among undershrubs 1/2 to 1 m high — principally *Acalypha claoxyloides* but also *Achyranthes*. These two 'weed' species are typically associated with biotic disturbance on Aldabra, *Acalypha* with disturbance by man and *Achyranthes* with disturbance by noddies.

Dead stumps of *Pemphis* suggest that herons in this type of habitat have continued to return to an acestral site after it has passed from its optimum of a former bush cover — possibly even a former tree cover, although no tree remains were found.

The same herbs are associated with these nests except where the *Acalypha-Achyranthes* thicket excludes the necessary light. Others with them are *Portulaca australis* and *Phyllanthus amarus*.

Other Ardeiformes

The only other common members of the heron group are Little Egrets (*Egretta garzetta*) and these favour the same types of site as grey herons, with more emphasis on the trees and bushes. Little Green Herons (*Butorides striatus*) sometimes occur in surprisingly large colonies in the mangroves.

Squacco Herons (*Ardeola ralloides*) and Cattle Egrets (*Bubulcus ibis*) are still present in numbers too small to have any significant effect on the vegetation.

Undergrowth nesters

Red-tailed Tropicbirds (*Phaethon rubricauda*)

Red-tailed Tropic birds or bosun birds nest on the ground under varying amount of plant cover. Usually the nest is invisible until the vegetation is parted but they are not hard to find because of the raucous screeching and lunging with open beak which starts when the intruder approaches within a few metres. It is unlikely that any land predator, even feral cats, would stand up to birds so aggressive but, in fact, both species of tropic bird were found only on the lagoon

islands where such predators are sparse or absent. They are reported, too, on Polymnie Island, smallest piece of the ellipse which forms the atoll rim.

Pairs may be solitary or in widely spaced colonies of up to about 20 per islet, but seldom closer than 2 m to neighbouring pairs, so having only local effects on the plants. Types of site favoured are as follows:

(a) under bushes

Bushes utilised are usually wind-trimmed to produce a dense meshwork of branching so that birds can be difficult to reach. *Pemphis acidula*, as the commonest bush of the islets, is most used. Other are *Suriana maritima*, *Desmanthus commersonianus*, *Sideroxylon inerme*, *Ficus reflexa* and *Lumnitzera racemosa*. Birds favour rocky sites rather than sandy ones and were not recorded under the three common shrubs of sandy coasts, *Tournefourtia argentea*, *Scaevola taccada* and *Guettarda* species.

(b) among undergrowth under bushes

Birds next under more depauperate specimens of the above bushes among a thick understorey of semi-shrubs, principally *Acalypha claoxyloides* with rather less *Achyranthes aspera*, the usually leafless (but flowering) *Plumbago aphylla* and wire grass (*Sclerodactylon macrostachyum*) with the softer grass *Dactyloctenium aegyptium* and a little *Eragrostis* sp., *Portulaca oleracea* and *P. australis* marginally.

(c) among semi-shrubs

Other birds are in the above understorey species with no shrub cover, although sometimes with the dead remains of unidentified shrubs protruding from the low canopy, so this is evidently a degenerated vegetation phase.

(d) in crevices overarched by plants

Parallel-sided holes in the champignon, overarched by varying amounts of herbs, grasses and undershrubs are used, the rock formation supplying the greater cover. Often these holes take the form of vertical chimneys more than half a metre deep and the diameter of the bird's head and body length, so that the long tail arches over the back, its tip beside the beak.

White-tailed Tropicbirds (*Phaethon lepturus*)

This slightly smaller species of tropic bird lays its purple-blotched eggs in sites similar to the above and also in more open sites — although rather less aggressive and therefore apparently more in need of protection. As both species produce eggs and chicks during the same period, the smaller birds may be excluded from better sites by the larger. Nesting occurs throughout the year, with no peak (Diamond, 1971). Often the two species are mixed in the same colonies, but some islets seem to be devoted exclusively to one, as the Ile Sylvestre near Esprit in the Western part of the lagoon where some twenty pairs of

White-tailed Tropic birds were located on 18th April, 1970. Even here there was no synchronisation of laying eggs, small chicks and fully grown ones with barred juvenile plumage being present simultaneously. Two further types of site and types (a) and (d) above are used on this island.

(e) crevices with no sheltering plants
Chimneys and crevices in the champignon with no overarching vegetation contain incubating birds fully visible from outside.

(f) open sand
Level sandy sites are usually near the foot of rock walls. In the rainy season (which is also the observed nesting season) these support a sparse growth of grass and herbs which has no concealing function. Commonest is the mauve-flowered member of the Caper family, *Cleome strigosa* (which, like *Plumbago aphylla* and *Acalypha claoxyloides,* is a group-endemic found only on the islands of Aldabra, Assumption, Astove, Cosmoledo, St. Pierre and Gloriosa in this corner of the Indian Ocean). Two soft-leaved grasses, particularly *Daknopholis boivinii,* but also the more generally distributed *Dactyloctenium aegyptium,* also grow. A few *Acalypha* seedling spring up beside nests in places or, more correctly nest hollows, no building material being used.

Part of this islet is heavily bushed but there is no evidence to suggest that the more open sites occupied by birds might once have been so covered.

Ground nesters

White-capped noddies (*Anous stolidus*)

Noddies (or noddy terns) are much the commonest species of ground nesting birds. Chosen sites range from bare rock to a low cover of semi-shrubs and larger shrubs (up to 3 m high) are used as perches. In the absence of ground nesting Blue-faced Boobies, they undoubtedly affect the plant life more than any other birds.

They occur almost exclusively on the smaller undercut 'mushroom islets' of perforated champignon rock in the lagoon. (Derivation of the name of 'champignon'for the predominant razor-edged reef rock is from the eroded mushroom shape of these islets, some of them no bigger than a large table).

Mangrove and *Pemphis*-dotted headlands of the larger encircling islands of the atoll rim are used for perching rather than nesting. The requisite condition appears to be unrestricted access to open water-where the noddies fish from the surface, like gulls, instead of diving for food like the more closely related terns. Even on an island so small as Latham, forty miles off Dar-Es Salaam on the East African coast, noddies occupy peripheral areas, leaving more central ones to sooty terns and blue-faced boobies. Aldabra habitats fall into the

following categories:

(a) on top of low, truncated undershrubs

The fact that noddies, unlike most species of tern, build quite substantial nests of twigs, mangrove leaves, sea grasses (principally the common *Thalassodendron ciliatum*), algae and quill feathers when such material is available, enables them to nest above ground level. This is something which is achieved by the tree-nesting fairy terns only at the expense of high mortality of eggs and chicks, Mary Penny having recorded only 3 successfully hatched young from 150 pairs studied on Cousin Island in the Seychelles (Penny, 1970).

It is improbably that mangrove leaves, one of the chief building materials, are plucked from the trees, as only dry, ginger-brown ones are seen in nests and these fall naturally, to float up against the nesting islets in quantity.

Nests are seldom more than 1/2 m above ground level on Aldabra, although White-capped Noddies on Heron Island, at the southern end of Australia's Great Barrier Reef, nest in the lower branches of *Pisonia grandis* trees, 3 m or more high, building their nests largely of *Pisonia* leaves (Gillham, 1963a).

Achyranthes aspera is the only undershrub seen to support nests on Aldabra, the plants chosen being dense and flat-topped, due either to wind-trimming, salt scorch or bird disturbance (including the plucking of upstanding twigs for nest material). *Acalypha claoxyloides*, second commonest plant of this conformation on the islets appears not to be utilised, due, no doubt, to the laxer mode of branching providing inadequate support. A parallel can be drawn with the undershrubs used by nesting crowned cormorants on islands off South Africa where dense *Helichrysum ericaefolium* and *Lycium ferocissimum* bushes are used but not the post-climax phase of laxly branched *Solanum guineense* and *Asclepias pubescens* which replaces these when the bird pressure has destroyed them (Gillham, 1963b).

Relatively few nests among the thousands observed on the Aldabra islets were thus sited, perhaps a dozen in all — the remainder being at ground level. One island of this type, recently vacated by noddies shows the following ground cover:

Achyranthes aspera	60%	*Sesuvium portulacastrum*	1%
Dactyloctenium aegyptium	30%	*Sida parvifolia*	1%
Boerhavia elegans	2%	*Corchorus aestuans*	1%
Portulaca oleracea	2%	*Phyllanthus ?amarus*	1%
Portulaca australis	1%	Bare rock	1%

(b) beneath low undershrubs

Although essentially birds of the open, noddies, like the bridled terns (*Sterna anaethaetus*) of Western Australian islands (Gillham, 1961), will occasionally build beneath the dense *Achyranthes* referred to above. Seldom are nests found more than 1/2 m in from the edge of the thickets and the entrance tunnel is always sufficiently wide for the bird to leave hurriedly with wings spread. Better camouflaged nests would be more difficult to observe and may occur, but no birds are seen rising from dense stands of plants.

Type (b) nests are usually on the same islets as type (a), such sites being less favoured on the whole than sites with sparser vegetation. A few nests are under *Acalypha* plants and all are on fairly level rock, not in deep pockets of the champignon such as are used by the closer-sitting tropic birds and form cul-de-sacs from which rapid escape might be hindered. Noddies are not, however, easily disturbed by intrusion, often allowing approach to within 1 m of the next before rising, and 'dive-bombing' the intruder vigorously when young chicks are present, although less belligerant during the incubation period. Off-duty birds perch extensively on the truncated surfaces of the *Achyranthes* thicket, from where they can communicate danger to those below.

Twigs at the thicket margins become denuded of leaves, but this damage appears to be physical rather than physiological and purple flower spikes are produced prolifically during the rainy season, concurrently with the observed nesting.

Some of the more robust stands of *Achyranthes* shelter only moribund nests, suggesting that this vegetation phase of low semi-shrubs might be principally a post-nesting phase, stimulated by birds and growing up on the more open sites which remain the most popular with current breeders. It is suggested that noddies, which have an obvious preference here for sites exposed to the sky, may be forced out onto the top of the scrub (type (a)) as the guano-stimulated 'weed' vegetation encroaches over their ground sites (type (b)).

A post-nesting phase of vegetation occurs when the *Achyranthes*, with increasing proportions of *Acalypha*, grows to heights of 1 m or more and is used by noddies only for casual perching — preferred perches being afforded by the more twiggy, smaller-leaved though taller *Pemphis acidula* bushes.

White-flowered *Ipomoea macrantha* and *Pleurostelma cernuum* twine among the less disturbed growths.

Some of the islets unoccupied by birds show a drying away of the *Achyranthes*-*Acalypha* undershrubs and colonisation by small *Pemphis* saplings with a few young *Ceriops tagal* mangroves marginally. Other islets have relict, morbund *Achyranthes* beneath a thriving *Pemphis* scrub — very patently a later phase of the same post-bird succession. Such islands have no grass or herb flora even in the rainy season,

these belonging to an earlier, more open seral phase, which is seen to advantage only on islets ungrazed by the giant tortoises.

The vegetation of certain islets supporting a combination of *Pemphis* with *Achyranthes-Acalypha* understorey seems to have a different origin. In these islets the *Pemphis* is morbund and the undershrubs thriving. Noddies perching on the upper storey of *Pemphis* kill back many of the shoot tips and deposit quantities of excreta which is apparently appreciated by the robust, white-splashed undergrowth.

These two types of community suggest a divergence of seral direction during post-nesting phases. If noddies desert the area completely the *Pemphis* thrives and shades out the interim stage of *Achyranthes-Acalypha;* if they return subsequently to roost in the higher *Pemphis* twigs the more guano-tolerant though lower-growing species may return and gradually come to dominate if pressure is sufficient to cause extensive die-back of the *Pemphis*. That this occurs is borne out by the total death of some of the large central *Pemphis* bushes on one such islet used by noddies. That roosting sites change, probably more frequently than nesting sites, is indicated by the presence of perching birds in bushes suffering little damage as yet.

Islets undistrubed by birds can, if of sufficient size, support a mixed scrub which includes *Sideroxylon inerme, Ficus nautarum, F. reflexa, Flacourtia ramontchii, Allophyllus africanus* v. *aldabricus* and *Suriana maritima*. Only the larger of these bushes have boughs broad enough to accommodate fairy terns' eggs, but they are visited by various of the heron-egret group, Souimanga Sunbirds *Nectarinia sovimanga,* Comoro Blue Pigeons *Alectroenas sganzini,* Madagascar Turtle Doves *Streptopelia picturata,* Madagascar Bulbuls *Hypsipetes madagascariensis,* and Madagascan White-eyes *Zosterops maderaspatana*.

(c) on prostrate grass mats

A small proportion of noddies nest on prostrate but still green mats of the broad-leaved grass, *Dactyloctenium aegyptium*. Nests in such sites often have fresh grass shoots incorporated in their structure. Areas pointed out by the Seychelloise boatman as having been previously occupied by birds showed this same grass as a dense flowering stand with shoots erect to heights of 30 - 50 cm and evidently benefitting from the residual nutrients of the droppings.

One islet showed two distinct *Dactyloctenium* communities in March 1970, part of it being occupied by a densely flowering stand 1/2 m high and part (three times as much) by a more tufted growth 15 - 30 cm high and only just coming into flower. This later growth apparently more recently vacated by birds, had the following floristic composition in terms of ground cover:

Dactyloctenium aegyptium	80%	*Sida parvifolia*	1%
Boerhavia elegans	10%	*Phyllanthus amarus?*	1%
Portulaca oleracea	3%	Bare Ground	5%

Quite commonly noddies in grass communities are among tufts of fine-leaved *Eragrostis* sp. or, occasionally, *Sporobolus virginicus*. This latter, the pan-tropical grass so common on most sandy or rocky shores at or just above high tide level, shows no special affinity for bird colonies, although it is the most generally distributed of the coastal grasses away from them.

Several mainly bare islands support a little dead and depauperate *Pemphis* and a spreading growth of *Sporobolus*, suggestive of shrub degeneration followed by a new secondary succession starting with this halophytic grass. Without some documentation of former bird activity, it is impossible to say whether this is a biotic or climatic-edaphic succession, and whether the cyclic changes are due to successive waves of bird occupation.

(d) on non-succulent herb mats

On slightly larger islets away from the immediate splash of the sea — which is effectively curtailed throughout at low water because of the deeply undercut nature of the periphery, ordinary low growing mesophytes may prevail. These only persist, however, under light bird pressure. Species concerned are *Boerhavia elegans, Cleome strigosa, Corchorus aestulans, Sida parvifolia* and *Tephrosia aldabrensis*. The sea convolvulus *Ipomoea pescaprae,* so much a feature of tern colonies on the sand of other atolls, was not recorded at all in the rocky Aldabra colonies, only the less arenicolus *I. macrantha*.

(e) on succulent herb mats

The three plant species most closely involved with noddies, with the possible exception of *Achyranthes*, are the three so-called sea purslanes, *Portulaca oleracea, P. australis* and *Sesuvium portulacastrum* in this order of abundance. The two yellow-flowered *Portulaca* species, together with *Ipomoea pes-caprae,* are the only plants to withstand pressure from the hosts of sooty terns, noddies, crested terns and blue-faced boobies on Latham Island (Gillham, 1972).

The pink-flowered *Sesuvium,* although very tolerant of guano, is not necessarily guano-induced, being a typical halophyte of both spray-splashed champignon and sandy beaches above the mangrove fringes.

Two similar-sized islets of slab-like platin rock, approximately 5 X 8 m, one occupied by noddies and one not, showed the following flora:

	Occupied islet	Unoccupied islet
Bare platin	20%	50%
Sesuvium portulacastrum	50%	50%
Portulaca oleracea	20%	
Achyranthes aspera seedlings	10%	

The establishment of young *Achyranthes* on the occupied islet suggests a progression to the semi-shrub stage — one which is parallelled by the semi-shrub stage of *Ballota africana* on South African bird islands (Gillham, 1963b).

Another bird-occupied island showed Sesuvium only in pockets around the seaward edge, the main body of the vegetation being a Portulacetum of the following composition:

Bare champignon rock	2%	*Dactyloctenium aegyptium*	2%
Portulaca oleracea	70%	*Portulaca australis*	1%
Boerhavia elegans	20%	*Phyllanthus amarus?*	0.5%
Cleome strigosa	4%	*Sida parvifolia*	0.5%

The whole of this community smelt powerfully of guano and was sprinkled with moulted feathers. All species were flowering but much of the *Dactyloctenium* was flattened and dead — as in the booby colonies of Wizard Island, Cosmoledo (Gillham, 1974).

This island and the next had, my Creole guide informed me, been quite bare of plants until the onset of the rains 4 - 5 months before. Evidently heavy bird pressure during droughts is lethal to herbaceous plants, whereas these will grow under the same bird pressure during the rainy season and (less well) with no bird pressure during droughts. The second area showed only a 50% ground cover of the following composition:

Sesuvium portulacastrum	15%	*Eragrostis* sp.	r
Dactyloctenium aegyptium	12%	*Sporobolus virginicus*	r
Achyranthes aspera	10%	*Cleome strigosa*	r
Portulaca oleracea	5%	*Boerhavia elegans*	r
Portulaca australis	5%	*Lagrezia oligomeroides*	r

(f) on naked champignon rock

Some nesting islets are completely without vegetation or with only minute patches of *Sesuvium* or *Sporobolus*. In the absence of vegetation the noddies build in shallow depressions of the champignon, sometimes straddling holes through which the sea is visible below. Eggs in these more open situations are sometimes destroyed by pied crows (*Corvus albus*) the herons also prey on eggs and chicks.

In some instances these islets may be too close to the high tide mark to support vegetation but, in view of the fact that they are not too close to support noddy eggs and chicks this seems unlikely (particularly as *Sesuvium* and *Sporobolus* are well able to withstand immersion

in sea water at high springs). Often they are the most crowded, so could conceivably represent the bare phase of a bird-controlled plant succession where most plant growth is inhibited. There are no records available to show whether islets which are bare of both plants and birds were once occupied by birds and also qualify for inclusion at the bottom of a biotically controlled sequence.

Few of the noddy islands appear to have any soil or even accumulations of blown sand (hence the absence in this work of what might have proved useful soil analyses in relation to guano deposition). Obviously, however, a rudimentary soil must exist, if only invisibly in crevices and convolutions of the old uplifted reef rock.

Blown sand is at a premium in the lagoon, where only small pocket beaches are exposed at low water, these often partially sheltered by mangroves so that the wind cannot pick up sand for transport to the bird islets. There remain the coral chippings, working gradually down into a clacareous dust under the influence of weathering, the considerable amount of organic nest material brought from the driftline and other vegetated areas by the noddies, and their guano.

From the physico-chemical and textural point of view the birds' contribution is vital as a prerequisite for plant growth. Noddies, therefore, which may destroy plants once established, may, nevertheless, be a necessary step towards their establishment in the first place. The type of vegetation present is likely to be as dependent upon the beneficial accumulations of past noddy populations as on the current increment of plant and animal residues from present populations. Current increments, undiluted during drought, are likely to prove detrimental; during light rain they may well prove advantageous to the growth of species tolerant of mineral salts; during heavy rains they are likely to be washed off into the sea and have no effect.

Plant communities subjected to varying seasonal pressures from animals are always delicately balanced — the degeneration - regeneration cycle moving on opposing directions as the pressures fluctuate.

Terns

Black-naped Terns (*Sterna sumatrana*)

These birds lay their eggs on bare rock in slight hollows scraped in the limestone shingle. There is no indication that any kind of plant cover is sought. Often there are no plants in the vicinity, often only a sparse covering of *Sesuvium*. One unusually well vegetated site showed the following seven species: *Cleome strigosa*, *Corchorus aestuans*, *Fimbristylis cymosa*?, *Eragrostis* sp., *Portulaca australis*, *Phyllanthus amarus*? and *Sclerodactylon macrostachium*.

These small terns are by no means colonial, their nests widely scattered with usually only one or two pairs per islet, so any effect which they might have on the vegetation is likely to be negligible.

Little Terns (*Sterna albifrons*)

This species is reported to breed on Aldabra but was not seen.

Sooty Terns (*Sterna fuscata*) and Bridled Terns (*S. anathaetus*)

Both these species breed on Cosmoledo Island but no on Aldabra. In view of the enormous abundance of Sooty Terns on other islands in this part of the Indian Ocean, it is as surprising that this species has not taken over some of the unused noddy habitats on Aldabra as it is that the Blue-faced Booby has not come to share the grassed, sandy and platin areas of South Island with the giant tortoises. Or would the lumbering passage of tortoises (*Geochelone Aldabrachelys gigantea*) weighing 300 - 400 pounds be too great a hazard for eggs and chicks at ground level and this the reason why ground nesting tropic birds, noddies and terns prefer the mushroom islets onto which the tortoises cannot climb? (During the present study tortoises were found only on Green Island among the smaller islands, a terrain unoccupied by birds and easily accessible from the lagoon waters through the tangle of mangrove roots and stems. Tortoises are very bouyant and swim well.)

Crested Terns (*Thalasseus bergii*)

These birds were not seen to be breeding during the February to May period, but small flocks were feeding. Several hundred birds frequent the *Avicennia marina* mangroves of Ile Esprit, perching only in completely dead trees and on the dead branches of moribund ones. The fact that they never seem to perch in living trees indicates that they cannot themselves be responsible for the death of the chosen perches. Tree sites are more favoured for resting than ground sites. Perhaps there is some predation by land crabs (*Cardisoma*) or coconut crabs (*Birgus*), but some terns consort with turnstones (*Arenaria interpres*) on the sand below the mangroves.

An ex-nesting site pointed out on Moustique Island was sandy with marginal *Sesuvium* and *Sporobolus* — species needing no encouragement by birds in this sort of habitat.

Caspian Terns (*Hydroprogne caspia*)

These are reported to occur but were not observed.

Burrow nesters

Crab Plovers (*Dromas ardeola*)

These large-billed waders are constantly seen in flocks of many hundreds among the Palearctic migrant waders from the north, particularly in the western part of the lagoon and on the western sea reefs, as at Anse Var, but seem to be scarcer in the east end, where most of the sea-birds congregate. They nest in sandy burrows, but not

apparently on Aldabra, although some of the overwintering population stays on through the summer (Penny, 1971).

Audubon's Shearwater (*Puffinus Cherminieri*)

This petrel was first discovered breeding on islets in the lagoon in 1967 and were not seen during the present study.

Exotics in bird-induced vegetation

Renvoize (1971) estimates that the total flora of Aldabra numbers some 206 species of which only 40 are exotics and as many as 31 are endemic. Man's influence has been slight and the exotic species have not spread much beyond the settlement on West Island and a few localised areas used as fishing camps by the Creoles. The only two having profound influence on the native flora, the she oak (*Casuarina equisetifolia*) and the coconut palm (*Cocos nucifera*) occur on sandy flats or more inland areas not used by nesting sea-birds.

The apparent total absence of exotic species from the Aldabra sea-bird colonies studied in a wide range of habitats, particularly in the Southern Hemisphere and usually quite remote from direct human interference, alien plants are conspicuous, often more abundant than natives and frequently excluding indigenous species altogether (Gillham, 1961).

The disturbance and trampling, which damages or kills existing plants, and the addition of phosphatic and nitrogenous nutrients paves the way for an influx of arable weeds and 'followers of man' — usually easily distributed species which thrive in areas fertilised deliberately or inadvertently by effluents of one sort of another in man-dominated areas.

Perhaps more remarkable than the absence of exotic weeds from the bird colonies it is the abundance of indigenous ones in the settlement. The native *Cleome strigosa* and *Sida parvifolia* compete on equal terms with the invasive *Strachytarpheta jamaicensis* and *Ricinus communis* seedlings on the open sand: native grasses, particularly *Daknopholis boivinii,* and the blue-flowered *Evolvulus alsinoides* mingle with the various Euphorbias and Amaranthys

The herbaceous vegetation of certain noddy islands bears some resemblance to that of the settlement and fishing camps, as does the local increase of *Acalypha claoxyloides* in less trampled parts of both.

Both pink and white-flowered Madagascar periwinkle (*Catharanthus roseus*) have been planted outside the Creole's shacks and have spread extensively from the sands of the settlement through the champignon undergrowth of the neighbouring *Casuarina* woodland — as at the Anse Mais and other camps. This species might have been expected in the sea-birds colonies, in view of its prevalence in nearby sooty tern

Table 1. Postulated Plant Succession on Lagoon Islets in Relation to Bird Pressure

This resembles the climax community utilised by frigates, boobies, fairy terns and passerines. Only if defaecation is into the water will this community remain stable under heavy bird occupation and not revert to scrub. In fact this usually happens on the lagoon coasts of the main islands but seldom on the smaller lagoon islets.

Roosting noddies or nesting herons

Damage to *Pemphis* and return of understorey of 'weedy' semi-shrubs

Increasing bird Pressure

Heavy occupation by noddies, tropic birds, herons,etc.

Return to herb phase

Drought and continued bird pressure

Return to lower herb phase or bare rock

Mixed shrubs
(or mangroves if sufficiently marine)

---No bird disturbance

Pemphis with little or no understorey

---Little bird disturbance

Pemphis with understorey of *Achyranthes* and *Acalypha*

Noddies squeezed out by vegetation.
---Lighter occupation by tropic birds, herons, egrets, etc.

The semi-shrubs *Achyranthes* and some *Acalypha* with a relict herb community

Continued occupation
---by noddies; Influx of tropic birds

Portulaca oleracea, *Dactyloctenium* and other herbs and grasses

Noddies depositing guano and quantities
---of organic nest material

Sesuvium and *Sporobolus* and pulverised reef-limestone chippings

Terns depositing
---guano but no nesting material

Bare rock — no soil, no plants

colonies, where rank growths spring up each year to be killed back when the birds return to nest. It was not found, however.

Three explanations are offered as contributing to the 'purity' of the bird flora:

(a) Lack of bird transport

Most of the bird colonies studied in other parts of the world have been visited by gulls, if not nested in by them, and gulls, as general scavengers and producers of only partly digested crop pellets (Gillham, 1970a) have ample opportunity for transporting viable plant disseminules from man-made habitats to bird-made ones. Not only are gulls (Lesser Black-backs — *Larus fuscus*) exceedingly rare on Aldabra, but none of the sea and shore-birds were seen to alight in the settlement apart from cattle egrets, squacco herons and turnstones which do not nest in the areas studied. Boobies fly over daily to their fishing grounds at sea — followed by the usual retinue of pirating frigate birds — and white-tailed tropic birds and noddies pass occasionally, but none of these alight.

Pied crows are commonest in the settlement and crows are known to produce crop pellets. Some of these which take eggs and chicks on the bird islands may hail from there but these supply the only possible link for bird transport of weed seeds.

(b) Lack of fertility-demanding ruderals

The usual attraction of bird colonies for weeds of cultivation is their fertility. Fertility on this notoriously inhospital atoll, where even coconuts fail to attain a reasonable size, is likely to be limited to the bird colonies. The weeds of the barren, porous, organic-deficient sands of the settlement cannot, of necessity, be demanding in their nutrient requirements, so this special attribute of the bird colonies is no special incentive to establishments should they by chance arrive.

Sea-birds, no doubt, nest outside the rainy season, but the present observations (February to May, 1970) were all made during the rains, so that chick growth and plant growth were proceeding side by side — the plants benefitting (or otherwise) from fresh, unleached excrement between showers.

Had the rainy season followed the nesting season instead of coinciding with it — as so often happens in less tropical habitats where plants invade during the rainy autumn following a dry summer nesting season, it is likely that the range of plants able to tolerate the ameliorated chemical conditions would have been wider.

(c) Availability of indigenous ephemerals

The abundance of European annuals in Australasian bird colonies is facilitated by the paucity of easily-dispersed, fertility-demanding annuals and ephemerals in the Australasian flora. This does not apply on Aldabra, where the terrain is so harsh that large areas become bare

during the dry season, to become recolonised by short-lived indigenous plants during the 3 to 4 months of the rains (approximately December to May). These pass the adverse drought season as seeds, many of the shrubs dropping their leaves then, so that shade as well as moisture is in short supply.

The herbaceous, vetch-like legume, *Tephrosia aldabrensis* (or *T. pumila* v. *aldabrensis*) and the shrub *Allophyllus aldabricus* (or *A. africanus* v *aldabricus*) are endemics of the less spray-washed bird islands. Group endemics found only on Aldabra and the other atolls within a few hundred miles are *Acalypha claoxyloides, Cleome strigosa* and *Plumbago aphylla* — all frequent members of the Cosmoledo bird colonies as well as Aldabran ones.

The major natural biotic disturbance on Aldabra is provided by the giant tortoises and no less than eight of the small herbs of tortoise-grazed turf feature in the limited flora of the more trampled bird colonies. These are *Boerhavia, Lagrezia, Phyllanthus, Portulaca, Sida* and the grasses *Dactyloctenium, Eragrostis* and *Sporobolus*. The wire-grass, *Sclerodactylon,* although not grazed sufficiently hard to become a turf species, is not immune by virtue of its high fibre content but is often eaten (Frazier, in litt.). The shrubs and semi-shrubs are denuded of their leaves up to a browse line set by the height that a tortoise can reach when propped up on another's carapace. Their regeneration is hindered by the grazing of seedlings and this may help to account for the fact that the particularly soft-leaved *Acalypha,* although a group endemic, is conspicuously more abundant around the living quarters of man and on the small sea-bird islets where tortoises do not normally occur.

Vesey-Fitzgerald reports "a herb mat community" particularly beneath dense bird colonies (presumably tree colonies) on other islands in the west Indian Ocean, but this has no direct parallel on Aldabra where most of the tree nesters return to the lagoon the quota of nutrients which they bring from the sea.

SUMMARY

The vegetation of the various types of site occupied by nesting seabirds on the uplifted atoll of Aldabra in the western Indian Ocean is discussed. Tree-nesting Frigate birds, Red-footed Boobies, herons, egrets, and White Terns have little modifying influence on the mangroves on which they next, their excreta being dispersed in the waters of the lagoon. Undergrowth nesters, principally Red-tailed and White-tailed Tropicbirds, have a slightly more pronounced effect. Terns nest sparsely and mostly in the open, but the more abundant white-capped Noddies range from bare champignon rocks to the tops of low *Achyranthes aspera* scrub. Their suggested role in the changing cycle of vegetation from succulent halphytes through mesophytic herbs and guano-tolerant undershrubs to shrubs is considered and offered in diagrammatic form. Attention is drawn to the unusual complete absence of exotics in the

bird flora and parallels drawn between disturbance by birds, tortoises and man.

ACKNOWLEDGEMENTS

My grateful thanks are due to the sponsoring and financing bodies enabling me to visit the atoll — the Royal Society of London and the Natural Environment Research Council — and to University College Cardiff for the granting of 5 months' sabbatical leave. Also, to Mr. J. Frazier of the University of Oxford, Mr. S. Renvoize of the Kew Herbarium, Mr. S. Kibuwa of the Nairobi Herbarium and Dr. B. Harris of the University College of Dar Es Salaam for identification of plants, to Mr. A. W. Diamond for information on where to look for sea-birds, to the late Cdr. G. Lush, M. B. E. and the others responsible for maintenance of the island outpost prior to the opening of the new research station and to Harry Charles, my Seychelloise guide.

REFERENCES

Beamish, T. 1970a. Killing of *Catharanthus roseus* by sooty terns. BBC Living World television programme.

Beamish, T. 1970b. *Aldabra alone.* London: Allan and Unwin.

Diamond, A. W. 1971. The ecology of the sea birds of Aldabra. *Phil. Trans. R. Soc. Lond.* B 260: 561-571.

Gillham, M. E. 1961. Alteration of the breeding habitat by sea-birds and seals in Western Australia. *J. Ecol.* 49: 289-300.

Gillham, M. E. 1963a. Coral cay vegetation, Heron Island, Great Barrier Reef. *Proc. R. Soc. Queensland* 83: 79-92.

Gillham, M. E. 1963b. Some interactions of plants, rabbits and sea-birds on S. African Islands. *J. Ecol.* 51: 275-294.

Gillham, M. E. 1970. Seed distribution by birds. *The flora of a changing Britain* (ed. F. Perring) : 90-98.

Gillham, M. E. 1974. Observations on vegetation of Blue-faced booby colonies on Cosmoledo Atoll, Western Indian Ocean. *Atoll Res. Bull.*, this issue.

Penny, M. 1970. Breeding success of fairy terns on Cousin Island, Seychelles. BBC Living World television programme.

Renvoize, S. 1971. The origin and distribution of the flora of Aldabra. *Phil. Trans. R. Soc. Lond.* B 260: 227-236.

ATOLL RESEARCH BULLETIN

NO. 201.

LIFE HISTORY NOTES ON SOME ALDABRAN LAND BIRDS

by C. B. Frith

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

LIFE HISTORY NOTES ON SOME ALDABRAN LAND BIRDS

by

C.B. Frith[1]

Introduction

The following observations were made during one year's residence (April 1972 - April 1973) on Aldabra Atoll, Indian Ocean (latitude 9° 24' S, longitude 46° 20' E) while I was a member of the Royal Society Research Station scientific staff. Although collection of the data presented here was incidental to other studies, daily nest inspections were made when possible and form the basis of this work. Notes made on the endemic weaverbird *Foudia eminentissima aldabrana* are not included here as they form a separate more comprehensive study (Frith, in press). Feeding data for most of the species listed also form another study and only a brief outline is given here. Data on *Centropus toulou insularis* are reported elsewhere.

Benson and Penny (1971) completely summarised the existing knowledge of land birds found on Aldabra and emphasized points requiring attention. The status of the species was found to be as given by Benson and Penny unless otherwise indicated. For the location of places given in this text I refer to a recent paper by Stoddart (1971).

Malagasy Kestrel, *Falco newtoni*

Sparse throughout the atoll, one or two birds being seen each day at various locations about the islands. Although being recorded as not found on Ile Michel by Benson and Penny three birds were seen in June and a pair with young were observed on this small island in October.

Coconut palm, *Cocos nucifera*, and stands of *Casuarina equisetifolia* trees appear to be favoured breeding sites, no nests being found in any other situation during this, or previous, studies. Benson and Penny expressed the view that the kestrel possibly colonized Aldabra subsequent to the introduction of palm trees by man. They concluded

---

[1] Formerly Royal Society Aldabra Research Station
(Revised manuscript received January 1975 -- Eds.)

this as the only known nest at that time was found in the crown of a palm tree. *Casuarina* trees are, however, equally used and there is some doubt as to whether this tree was introduced or is naturally present on Aldabra.

Feeding

The two endemic geckos, mostly the diurnal species *Phelsuma abbotti*, and the endemic skink, *Ablepharus boutonii*, plus various large insects form the basis of the diet. Twice I saw a kestrel eating a small rat (*Rattus rattus*). Benson and Penny suggest that small birds are taken but I did not see any evidence of this, nor did I see a small bird showing any fearful reaction to kestrels.

Behaviour

Unlike the observation of Benson and Penny more than two individuals in close association were seen. Three adult birds were observed flying and gliding together in a playful fashion in strong winds during June. During an inspection of an active nest the resident pair was assisted by a neighbouring pair (which had recently lost a clutch to predators) in mobbing me, all four birds flying at, and sometimes striking me. Pied Crows, *Corvus albus*, and vagrant Eleonora's Falcons, *F. eleonorae*, and Broad-billed Rollers, *Eurystomus glaucurus*, were mobbed by kestrels.

Breeding

On 18 August a pair was seen to copulate in the upper dead branches of a tall *Casuarina* tree in palm grove. Both birds held wings extended and dropping and called continuously.

A pair was found nesting in the crown of a palm tree at Anse Mais on 28 October but the tree could not be climbed. Another nest containing one egg was found thirty feet high in the crown of a palm near Old Settlement on 28 August: on being examined twenty days later it was found to be empty. A nest found on Ile Michel on 21 October was in a hole in a Casuarina tree approximately forty feet high. It contained three nestlings in off-white down, the youngest being three or four days old.

A fourth nest was located on 10 September when the remains of one egg were seen to be carried from it by a Pied Crow. On the 11 September this nest contained three eggs, the original clutch with little doubt, therefore, consisted of four. The eggs were laid in a hole in a large *Casuarina*, formed by the loss of a large bough, approximately forty feet above the ground. The tree was situated in the centre of human dwellings, directly between two occupied houses. The history of this nest follows:

10 October 1972	3 eggs
12 "	1 egg, two nestlings
13 "	3 nestlings
21 "	Empty, almost certainly predated by Pied Crows.
9 November	1 egg
12 December	1 egg
22 December	Empty

The incubation period for the original clutch was at least 31 days. Throughout this pair's breeding attempts they were continuously disturbed by Pied Crows, causing them to spend much time in nest defence. The population of crows about Old Settlement is relatively very dense (ca.40) and is supported by food made available by man. One parent kestrel was so continuously chased and attacked by crows at the nest that it fell into a fresh-water tank and nearly drowned. It was helped out of the water by a woman then spent several days perched at the nest entrance recovering.

White-throated Rail, *Dryolimnas cuvieri aldabranus*

Feeding

I have little to add to what Penny and Diamond (1971) published save one or two observations confirming more unusual food items.

An immature rail was seen to kill and eat a small ghost crab, *Ocypode cordimana*, measuring approximately one inch across the carapace. Odd legs detached during killing were swallowed first, the remainder being swallowed whole.

Five rails were watched attacking and eating Green Turtle hatchlings, *Chelonia mydas*, which had erupted from a sandy beach in bright sunshine (Frith, in preparation). Unhatched turtle eggs, exposed by me, were also immediately taken by rails and eaten. The turtle hatchlings were not eaten whole but were pecked about the carapace and eaten in small pieces. The hatchling turtles broke surface at the same spot and their appearance was anticipated by the rails, the birds standing over the hatching point and probing the sand to the full length of the bill. Such probing was performed with an open bill, with the nictitating membrane covering the eye during deeper thrusts. Upon contact with a submerged turtle the bill was tightly closed about the prey, the head shaken sideways and the turtle extracted vertically. Details of this activity were obtained by simulating erupting turtles. This I did by burying an extended leg

in the beach sand with my toes pointing upward several inches beneath the surface. By slowly wagging my toes a very slight movement in the surface sand was caused and attracted four rails from up to 3 metres away. They rushed to the disturbed spot and probed in the above described way. Two individuals returned to the spot after an absence of several minutes and probed again, without any movement being produced to attract them.

I once saw a rail disturbing the nest of a red wood ant, *Camponotus maculatus*, by pecking at it and feeding upon eggs, larvae and some adults.

Behaviour

The White-throated Rail apparently thrives in areas supporting considerable numbers of introduced rats, *Rattus rattus* (Penny and Diamond). I observed one interaction between these two animals. An adult and a large immature rail were observed feeding upon camp scraps when a large male rat appeared and slowly approached the food. As soon as it was observed by the rails the adult bird walked directly at it and pecked it severely on the nose. This action was attempted at each advance of the rat but after the initial peck the rat avoided further physical contact and slowly retreated, finally leaving altogether. Throughout this eviction the immature rail continued to feed, showing no fear of the rat a couple of feet away.

Short copulation sequences were witnessed twice in May (out of breeding season) performed by the same two birds, the ceremony being the same in both instances. The female bird had the brighter pink bill base which agrees with the findings of Penny and Diamond. The apparent soliciting posture of the female consisted of spreading and lowering the white outer tail feathers and lowering the bill until the tip touched the ground. The male mounted and dropped a wing either side of the female, gave two or three thrusts of the body and hopped down. Upon dismounting the male walked about the female with head held stretched forward and downward and wings spread and slightly raised. As active nesting is recorded for November and December (Penny and Diamond; C. Huxley, *pers.comm.*) it is considered unlikely that the above copulation postures had anything to do with reproduction. Of a number of copulations observed by Penny and Diamond only two were followed by a display, apparently identical to the above described. These were performed by a male after mounting a female to which he was not paired. It would seem possible, therefore, that some ritualised mounting takes place between unpaired birds which is directly followed with a postcoital display from the male. This is supported by the fact that other copulations between known paired birds were followed by no displays, the birds simply separating to feed (Penny and Diamond). Penny and Diamond suggests the postcoital display is connected with the status of a male as an intruder in an occupied territory.

Penny and Diamond recorded that the White-throated Rail was never seen to use the feet as weapons but referred to an account by Abbott, in Ridgway (1895) of birds "flying at each other like game cocks". An instance of the latter was observed once. The two birds concerned were of the same brood, being ringed as large young in the company of an adult on 17 April 1972. The fight took place on 30 May 1972 and was apparently a dispute for presence in the immediate area of some resting people and their food scraps (i.e. feeding territory). The birds faced each other, a foot apart, with bill lowered and giving an occasional low grunt accompanied by a short upward flick of the bill. Suddenly, both would leap at the other feet first, beating the wings and vigorously kicking. Should one bird get a good grip both tumble the ground severely pecking at each other. Fights such as this could result in permanent damage. Whilst marking one bird my hand was quite deeply cut as a result of the kicking action. It is possible the bastard wing claw of this species is utilized during fights, particularly as wing beating was conspicuous.

Notes

During the period October 1967 - February 1968 Penny and Diamond ringed 23 birds at Middle Island Camp and 13 at Anse Coco. During the term of the present study the author and other workers visited the two localities fairly frequently, usually for at least several days at a time. Only one marked bird was noted at each location. The individual seen at Anse Coco in May 1972 was marked as an adult during June 1968. The marked bird seen at Middle Island in October 1972 was originally ringed in October 1967 as an adult. Thus these two birds had lived at least five and six years respectively. Lack of sightings of any other marked birds is not necessarily indicative of mortality. Penny and Diamond found that the rail population was to some degree transient. It is also possible the camps of these workers attracted large numbers of rails which, after the departure of the men, dispersed from the area and would not have again been attracted to the smaller, more temporary, camps since.

Comoro Blue Pigeon, *Alectroenas sganzini minor*

The Blue Pigeon is noticeably more common at localities as close to West Island as Anse Mais and Anse Polymnie than at the former locality. It is possible this is due to a lack of suitable foods on West Island but it is equally possibly due to predation by man in the recent past. Small flocks were commonly seen on the lagoon islands, Ile Michel and Ile Esprit, and were to be frequently seen flying strongly about the atoll. Of particular note (at least during August) were very large numbers of birds flying from Middle Island to South Island, across East Channel, in the morning and returning in the evening. Birds flew across the channel singly or in small flocks of

up to fifteen, at a height of approximately 25 to 40 feet. Many hundreds of birds performed these flights daily.

Feeding

This species was never seen on the ground. Lone birds and flocks of up to twenty were observed feeding on various fruits and berries which were picked from the plant. The arboreal feeding of this species considerably limits any competition between it and the only other pigeon on Aldabra, *Streptopelia picturata coppingeri*, which is a ground frequenting seed eater.

Behaviour

When not feeding birds were typically seen in bare, higher, branches. A type of display was observed, given by one bird to another, on two occasions (once in upper bare branches of *Casuarina* in April and once in mangrove in May). One bird flew to perch a foot or two from the other, lowered the head gently until horizontal with its feet, raised the rather elongate feathers of the neck, and shook the head. The head was shaken perhaps one inch either side of the normal position, and was reminiscent of a pigeon regurgitating food. No distinct bowing of the whole body took place, but a low grunt-like "weow-weow" was uttered. This was undoubtedly a directed display which is possibly a ritualized regurgitation, or feeding, action or ritualized nest building ("nodding" Goodwin, 1967). Benson and Penny record nesting during January and February (1968) and it is therefore probable that the above display was given toward the end, or after, breeding.

Notes

Two individuals observed feeding closely were seen to have slightly aberrant plumage. Both had a noticeable amount of white in the upper wing when extended, though not extensive, and one had the central tail feathers pure white and so gave the tail the appearance of being white bordered with blue instead of uniform blue.

Aldabra Drongo, *Dicrurus aldabranus*

Feeding

Benson and Penny considered this species to show a marked preference for mangrove but my observations indicate that stands of Casuarina are equally favoured. Some authorities consider the *Casuarina* recently introduced onto Aldabra, in which case it might be used as a suitable substitute for mangroves, particularly as reptiles are available in the former but not the latter habitat.

Observed feeding activity suggests that, in habitats other than mangroves, small reptiles are eaten as much as are insects. Geckoes, skinks and larger insects are pounced upon, taken to a perch upon which they are pounded and are then ripped apart whilst held to the perch by the feet. Insects are commonly hunted in flight, often high above the tallest trees. No records of feeding in mangroves were made, possibly due to limited visibility and time spent in the habitat. Benson and Penny's suggestion that this species eats other birds is considered most unlikely. No fear of drongoes was noted.

Behaviour

Commonly seen in family parties (immatures having a grey and whitish plumage) of about four birds, feeding together by perching in exposed branches and pouncing on prey within a small area of relatively open ground. Lone birds or pairs were seen to severely mob and strike fruit bats *Pteropus seychellensis*, Green-backed Herons *Butorides striatus*, Pied Crows *Corvus albus*, kestrels *Falco newtoni* and the migrant Eleonora's Falcon *F. eleonorae* and Grey Cuckoo *Cuculus canorus* (presumably reacted to as if a falcon as the Drongo has evolved without the presence of a parasitic cuckoo) at various times of the year. Human intruders near an active nest were also mobbed and sometimes struck.

One odd observation of pair activity was made in the middle of the non-breeding season (June). Two adult birds were seen perched by a fresh water pool. They then flew to a nearby tree where one bird picked off a dead leaf and offered it to the other. The second bird took the leaf and then dropped it.

A simple display was observed to be performed by an established pair of birds involved in nest building. The smaller bird added material to the nest and then flew to perch nearby where it was joined by its mate. The birds faced each other holding the bills slightly above horizontal and shook the wings vigorously and wagged tails from side to side. During this display both birds produced soft high pitched squeaky twitterings. This was not unlike young birds begging and possibly functions in maintaining the pair bond for part, or all, of the breeding season.

Breeding

Breeding activity was first noticed in mid September and continued until at least early January after which the species was not studied due to other work. Three pairs were observed at the nest, two only temporarily but one over a period of three months. All six nests involved were built in the fork of twigs of *Casuarina* trees. Nest examinations were made by use of a 'mirror-stick'.

One nest found on 5 November 1972 was twenty-five feet above ground in palm grove, with some *Casuarina* trees, and contained a single egg. An examination on 18 November found the nest empty. Another nest was found on 4 December twelve feet high, in palm grove with Casuarinas, containing one egg. Subsequent examination on 7 December found only one egg, which was gone on 12 December.

The breeding of a pair found close to the research station is worth recording as a number of interesting points were established. The very beginning of a nest was found on 25 September 1972 in *Casuarina* woodland. It was placed twenty-five feet above the ground and consisted of spider webs attached to the supporting fork and a very sparse bowl of fine twiglets. At this early stage birds were seen to sit in the very flimsy bowl and shape it by vigorously pushing down and outward with the breast.

The (continued) persistence of this pair of drongoes was remarkable. At the start of breeding a nest was built in little more than twenty days and a clutch of three laid which was predated. A second nest was built, utilizing the last, and was completed fifteen days after predation upon the first clutch. This second nest was found under 'deconstruction' four days after previous examination and it is possible a second clutch was laid and predated in the interim. The third nest took certainly less than fifteen days to complete in which a clutch of two was laid. This nest was predated and a fourth built in a period of ten days or less in which at least one egg was laid and predated. A fifth structure was not attempted, but the fourth was added to and a clutch of two eggs produced no more than fourteen days after predation upon the previous. This final clutch was predated and no further breeding attempt by this pair was noted as the birds apparently left the area. At least four, possibly five, clutches were laid by the female of this pair. It is interesting to note that as the season progressed nests were constructed in faster time, material from the previous structure being utilized despite an apparent abundance of suitable materials in the immediate area. Also of interest is the original clutch of three followed by clutches of two.

Eggs examined agree in colour with those described by Benson and Penny. A clutch of two measured 26.2 x 19.4 and 26.3 x 19.0 mm. Nest building and incubation of eggs was observed to be carried out by both sexes, no calls or displays being given during take-over of the latter duty.

Pied Crow, *Corvus albus*

Feeding

Other than from human settlement and temporary camps food is almost exclusively obtained on the beaches, open beach crest and coastal grassland areas, where various Crustacea appear to form the basic diet (in particular ghost crabs *Ocypode* spp., and hermit crabs *Coenobita* spp.). The fact that approximately fifty per cent of the entire crow population relies upon man's discarded food suggests that natural food sources may be limited for this species. Pied Crows are extremely predatory upon eggs and nestlings of other land bird species. Diamond (in Benson and Penny) found them taking eggs of tern species. Crows were often seen perched on top of the nests of *Foudia eminentissima*, ripping through the roof of the chamber or pulling the whole structure to the ground. As described above crows severely predated upon kestrels in the vicinity of Old Settlement. They were also seen to extensively mob migrating falcons, *Falco eleonorae* chasing them to great heights and over considerable distances.

Dying and dead giant tortoises, *Geochelone gigantea*, would obviously provide temporary large food sources for crows. Pied crows were twice observed to quickly appear at the location of a daylight eruption of Green Turtle hatchlings, *Chelonia mydas*, and to eat them (Frith, 1975).

Breeding

Benson and Penny recorded a nest containing three eggs in a coconut palm during December and one inaccessible nest was seen, apparently with attendant birds, during each of November, December and January. Two nests were found on West Island during the present study, both approximately forty feet high in the tops of Casuarina trees on beach crests. One, which could not be reached, was seen to have a pair in attendance on 1 July but was considered unlikely to contain eggs or young at that time. The second nest was discovered on 9 November containing three eggs and two nestlings. On 19 November only three eggs remained one of which was smashed, these were obviously addled. The nestlings would not have been old enough to have fledged. This same nest was examined on 17 December and contained four fresh looking eggs but no further examinations were made. During twelve months casual observation of the Pied Crow population on West Island only three young birds were noted (other than nestlings), on 12 November, in close association within a large flock. Possibly limited food and longevity restricts the reproductive rate.

Souimanga Sunbird, *Nectarinia sovimanga aldabrensis*

Feeding

Feeding takes place in all habitats but to a far lesser degree in mangroves than elsewhere, food consisting primarily of flower nectar and insects in that order.

Behaviour

Out of the breeding season flocks of from three or four to approximately thirty birds, in both male and female plumage, were commonly seen engaged in some form of chasing activity. This took the form of flying in very close association swiftly through vegetation giving excited twittering calls. Such behaviour was most commonly observed just after breeding and may therefore be the result, or cause, of territorial breakdown.

Males in full breeding plumage typically perch on conspicuous twigs and sing loudly. A 'bill up' display was commonly given by males to both females and other males, facing the recipient and raising the bill to almost vertical and thrusting the chest out. This display probably functions in both territorial and initial courtship confrontations.

A simple nest-site selection ceremony was observed several times. A male and female would fly to a potential nest site and perching on, or clinging to, available material situate themselves very close to each other. The material to which the intended nest was to be attached was pecked and billed, mostly by the female. During this mutual inspection, lasting approximately two minutes, a soft twittering was produced by both birds. Suddenly both birds would leave the nest site, the male to perch nearby and the female to collect spider web for the nest foundation.

Breeding

Active breeding was observed from August 1972 through to April 1973. This very early start to breeding (compared with other passerine species) preceded the start of any increase in insect abundance (fig. 1), unlike other species more dependant upon insect food. As this species feeds predominately upon nectar its breeding possibly correlates more closely with available nectar but unfortunately the latter was not assessed in any way. It was noted however that earlier breeding attempts were less successful until, that is, insects became more numerous (for feeding young). Nevertheless several clutches were laid in early September and one brood had fledged before the end of that month.

Breeding occurs in all habitats with vegetation higher than grasses. Five successful nests were located in and upon buildings constantly in use by people, one being in an occupied bedroom and another in a noisy and well used workshop. Benson and Penny give detailed descriptions of nests and sites.

Only the female nest builds, the male often following her as she searches for material and adds it to the structure. One female observed during her first day of nest construction flew between the nest and spiders webs forty feet away thirteen times in seven minutes. Only four successful nests were timed in their construction from start to finish (egg laying), but it is interesting to note, however, that structures built earlier in the season took longer than those built during the height of it:

Nest started	No. of days to egg laying
21 August	31
11 October	21
16 November	8
9 December	9

Nests were observed to be constructed much faster than eight days, but were not timed. Nests predated early in the season were abandoned and another built closeby. Nests predated in the height, or toward the end, of the season were usually added to for a day or two and re-used.

Of twenty-four clutches examined twenty-three consisted of two eggs and the other of one egg. As predation of part clutches was found to be common it is probable that the one egg clutch was the result of predation between nest inspections. Eggs are laid at approximately twenty-four hour intervals, mostly during the early morning hours.

Males take no part in incubation. Length of incubation, from the date of second egg laying, was found in five clutches to be thirteen days, in three clutches fourteen days and in two clutches fourteen to fifteen days. These periods fall within the variation given by Skead (1967) for a single sunbird species. The usual pattern is for one egg to hatch one day and the second the next, (in one clutch only did both eggs hatch on the same day), incubation starting with the first egg. Twenty-two eggs averaged 15.7 x 11.1 mm. the variation being 14.4 - 17.4 x 10.4 - 11.6 mm.

Nestling sunbirds react to the arrival of a parent immediately after hatching, a nestling being seen to beg vigorously as the nest was touched although still freeing itself from the egg. Nestlings are fed by both parents although several hourly observations indicated that

the male contributes only a third or less to feeding visits. Nestling period varied from fourteen to seventeen days, averaging fifteen days. Young of the only two successful broods of two fledged on the same day. In four clutches one egg did not hatch and disappeared a few days after the other egg hatched. In one brood of two, produced early in the season when insects were relatively sparse (fig. 1), one nestling died of starvation.

Notes

Only a single family of sunbirds was marked with colour rings but subsequent observations of them proved interesting and indicated that established pairs return to the same breeding territory season after season. The family concerned consisted of a pair and their single nestling. All three were individually marked at the nest site on 12 April 1972 (when the young bird fledged). The immature bird was still begging on 4 May, twenty-two days later, but on 10 May appeared quite independent and was feeding itself extensively. All three birds were regularly seen, together or separately, within a hundred foot radius of the original nest location until 26 June after which the immature was absent (next being seen on 13 December 250 yards from parents' territory). The parent pair was continuously observed within their original territory, and nested again in almost exactly the same spot as the original nest, until I left the atoll.

Malagasy White-eye, *Zosterops maderaspatana aldabrensis*

Status

This bird does not benefit from the groves of coconut palms as do several other passerine species and was rarely seen in that habitat unless *Casuarina* trees or bushes and shrubs (i.e. introduced cotton) were plentiful. It was abundant in mangroves, where many other land bird species were not but, like Benson and Penny, I found no nest in mangroves.

Feeding

Diet consists predominantly of insects save for the taking of some flower nectar, fruits and a little seed. Insects are mostly taken from foliage in typical *Zosterops* fashion, being picked from the surfaces of leaves. Birds feed in loosely associated flocks of from three or four to about thirty birds and move through vegetation quickly. Benson and Penny considered the White-eye to have no particular habitat preference but data obtained by myself indicate that *Casuarina* woodland firstly and mangrove secondly are preferred feeding grounds (Frith - in preparation).

Breeding

Reproductive activity was not noted until early December (fig. 1), considerably later than *Nectarinia,* and eggs were still being laid during late March 1973. Nests have been described in detail by Benson and Penny. I found them in all habitats except mangroves, and only rarely in palm groves.

Five complete clutches consisted of three eggs. A previous record of a two egg clutch (Abbot - in Ridgway, 1895) was possibly an incomplete or part predated one. Six clutches were observed and all were predated, almost certainly all by rats (particularly abundant about the research station where the nests concerned were located). One pair of birds was observed to produce three successive clutches, a new nest being built, quite close to the last, for each clutch.

The pale green eggs are laid on successive days. Average size of nine eggs (three complete clutches) were 15.5 x 12.0 mm., the extreme length and width being 17.1 and 11.5 mm. respectively. Both sexes incubate. Average weight of twenty-two live birds was 8.3 g. varying between 7.2 and 10.2 g.

Summary

1. Various life history notes on some Aldabra land birds were collected, incidentally to other work, during a twelve month residence on Aldabra Atoll. The majority of data presented concerns breeding biology and is new or supplementary to previous knowledge.

2. Data are given for Falco *newtoni, Dryolimnas cuvieri, Alectroenas sganzini, (Centropus toulou), Dicrurus aldabranus, Corvus albus, Nectarinia sovimanga* and *Zosterops maderaspatana.*

3. Breeding seasons of the more insectivorous bird species were found to coincide with an increase in insect abundance except in *Nectarinia sovimanga.* It is suggested that the latter species may commence breeding as a result of an increase in nectar abundance, prior to an increase in insects.

Acknowledgements

I thank all those present with me on Aldabra for bringing many and various points to my attention. In particular I thank Mr. L. Mole who utilised much unintended time on Aldabra searching for bird nests, including a total of fourteen hours spent watching activity at a coucal nest. Thanks also to Antonio Constance and Harry Charles whose observations and skill with ropes enabled me to frequently examine kestrel nests.

I am very grateful to staff of The Royal Society of London and to the staff of the British Museum (Natural History) concerned with Aldabra, and the ornithological department, for assistance in numerous respects. Thanks to Dawn W. Frith for unpublished figures of insect abundance for Aldabra.

References

Benson, C.W., 1967. The birds of Aldabra and their Status. *Atoll Res. Bull.* 118: 63-111.

Benson, C.W., and Penny, M.J. 1971. The land birds of Aldabra. *Phil. Trans. Roy. Soc. Lond.* B. 260: 417-527.

Frith, C.B. 1974. New and interesting observations of migrant and vagrant birds for Aldabra, Farquhar and Astove atolls, Indian Ocean. *Bull. Brit. Ornith. Club.* 12-19.

Frith, C.B. In press. A twelve month study of the Aldabra Fody, *Foudia eminentissima aldabrana* (Ploceidae).

Frith, C.B. 1975. Predation upon hatchlings and eggs of the Green Turtle, *Chelonia mydas,* on Aldabra Atoll, Indian Ocean. *Atoll Res. Bull.* 185: 11-12.

Frith, C.B. In preparation. Feeding ecology of some land birds on West Island, Aldabra Atoll, Indian Ocean: a preliminary survey.

Goodwin, D. 1967. *Pigeons and doves of the world.* London. Trustees of the British Museum (Natural History).

Penny, M.J. and Diamond, A.W. 1971. The White-throated Rail *Dryolimnas cuvieri* on Aldabra. *Phil. Trans. Roy. Soc. Lond.* B, 260: 529-548.

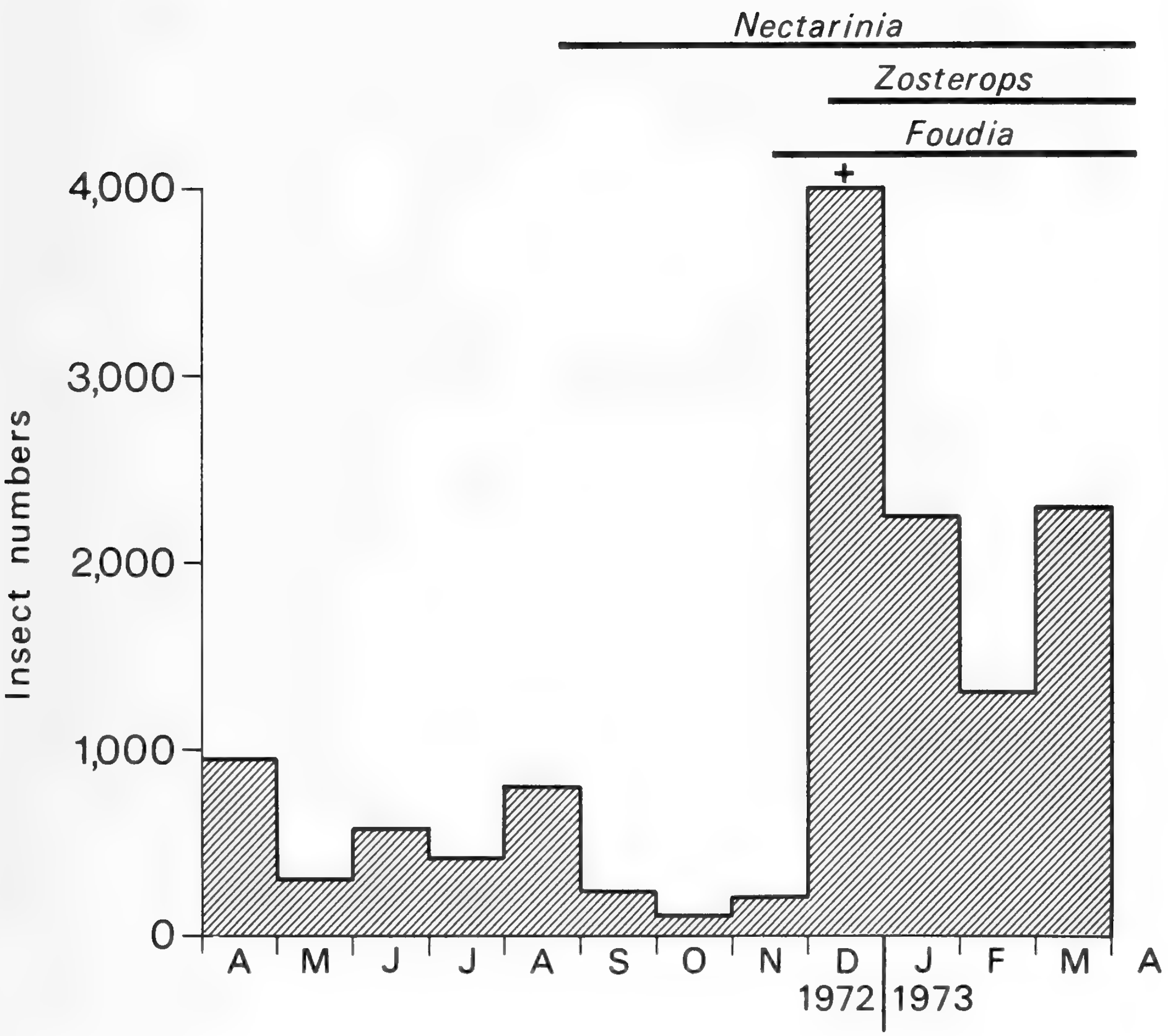
Ridgway, R. 1895. On birds collected by Dr. W.L. Abbott in the Seychelles, Amirantes, Gloriosa, Assumption, Aldabra, and adjacent islands, with notes on habits, etc.,by the collector. *Proc. U.S. natn. Mus.* 18: 509-546.

Skead, C.J. 1967. *The sunbirds of southern Africa.* Cape Town. Trustees of the South African Bird Book Fund.

Stoddart, D.R. 1971. Place names of Aldabra. *Phil. Trans. Roy. Soc. Lond.* B. 260: 631-632.

Watson, G.E., Zusi, R.L. and Storer, R.E. 1963. *Preliminary field guide to the birds of the Indian Ocean.* Washington. Smithsonian Institution.

Fig. 1. Monthly insect abundance on West Island, Aldabra Atoll. Totals are numbers caught during daylight hours by a Johnson-Taylor Suction Trap during one week of each month (by kind permission of Dr. Dawn W. Frith). The breeding periods for *Nectarinia, Zosterops* and *Foudia* are illustrated. Note that *Foudia* and *Zosterops* commence breeding with an increase of insects but *Nectarinia* starts remarkably earlier (see text).



Nectarinia
Zosterops
Foudia
+
4,000
3,000
2,000
1,000
0
Insect numbers
A
M
J
J
A
S
O
N
D
J
F
M
A
1972
1973

ATOLL RESEARCH BULLETIN

NO. 202.

CLIMATE OF ALDABRA ATOLL

by D. R. Stoddart and L. U. Mole

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

List of Tables

1. Records at Aldabra of (a) absolute maximum monthly temperature, (b) mean maximum monthly temperature, (c) mean minimum monthly temperature, (d) absolute minimum monthly temperature, (e) monthly rainfaill, (f) mean monthly wind speed, and (g) mean monthly atmospheric pressure, 1967-1973.
2. Annual records of (a) mean monthly wind speed and (b) mean monthly atmospheric pressure at Aldabra, 1968-1973.
3. Mean monthly rainfall at Aldabra based on pre-1959 records, 1967-1973 records, and all available data.
4. Monthly rainfall records and mean monthly rainfall for Aldabra, all available records.
5. Relationship between annual rainfall and number of days in the year with rainfalls of 10-25 mm, 1968-1973.
6. Frequency and duration of wet and dry periods at Aldabra, 1968-1972.

CLIMATE OF ALDABRA ATOLL

by

D. R. Stoddart[1] and L. U. Mole[2]

Introduction

Weather records have been maintained by the Royal Society at Aldabra Atoll (9°24'S., 46°20'E.), southwest Indian Ocean, continuously since mid-October 1967. The recording station is located on West Island, on the northwest side of the atoll, first at the Settlement, but after 1970 at the Royal Society Research Station 1 km to the south. These are both leeward and rather protected situations. A single synoptic observation is taken at 0600 GMT (0900 local time).

Records for the period November 1967 to October 1968 were very fully analysed by Farrow (1971), in the light of general information available for the southwest Indian Ocean, and the rainfall records up to 1970 were placed in a regional context by Stoddart (1971). Records now available since 1967 in some respects modify these preliminary reports and also permit a more detailed analysis of ecologically significant parameters such as rainfall frequency and duration of drought. This paper presents an abstract of the climatic data to the end of 1974 (seven complete years), with fuller analysis of the daily rainfall records for the five years 1968-1972. Daily observations for the period of record are available on request from the Royal Society.

In addition to these records J. Frazier maintained rainfall records at Dune Jean-Louis on the exposed south coast for most of the period July 1969-June 1970, and G. E. Farrow made records at East Channel on the northeast side of the atoll during September-October 1968. A more detailed investigation of local and microclimate is now being made by R. J. Hnatiuk.

---

[1] Department of Geography, Cambridge University, England.
[2] The Royal Society, London, England.
(Manuscript received May 1975 --Eds.)

Pressure and Winds

Farrow (1971, 69) points out that during winter pressure is high and the Southeast Trades blow strongly, while in summer pressure is low and winds are lighter and northwesterly. Records for 1968-74 (1969 is absent because of equipment failure) confirm this pattern (Table 1 and 2; Figures 1f, 1g and 2). These show substantial agreement from year to year in pressure distribution, with a maximum in July, but considerable variability from year to year in mean monthly wind speed. 1970, 1973 and 1974 were years with generally low wind velocities, and 1972 a year of high velocities. 1971 was characterised by abnormally high wind speeds in February and March. Although both 1970 and 1973 had similar wind patterns, the former was an exceptionally dry year and the latter exceptionally wet.

Table 3 gives the number of occurrences in each month of calms, of winds in excess of 10 kts, and of winds in excess of 20 kts at the daily recording time. Calms are rare (less than 10 days per year except in 1971). The frequency of winds higher than 10 kts varies from year to year, being low in 1969, 1970, 1973 and 1974 and high in 1971 and 1972. As with mean monthly wind speed there is no obvious correlation with rainfall, though moderately high winds (10-20 kts) are most characteristic of the Trade Wind months August-October. Table 4 lists the maximum wind speeds recorded in each month. Occasional summer squalls bring speeds greater than 30 kts. The maximum wind speed recorded is 44 kts on 21 September 1968; the maximum in most months is less than 20 kts.

Temperature

Figure 1 a-d gives curves of absolute monthly maximum (a), mean monthly maximum (b), mean monthly minimum (c), and absolute monthly minimum (d) temperatures over the period of record; maximum temperatures are missing for the period November 1969 to March 1970 because of instrument failure. Corresponding data are tabulated in Tables 5-8. The annual range in mean monthly temperature is about 4°C. The monthly range is least in winter (July-August) and greatest in summer (January). The 1967-74 averages of mean maximum and minimum monthly temperatures do not rise about 31.24°C (December) or fall below 22.15°C (August), respectively. The highest temperature recorded is 36.3°C and the lowest 17.5°C. Temperatures fell below 20°C on only eight occasions during the seven years 1968-74; four of these occasions were during the winter of 1969.

Rainfall

Three complete and four incomplete years of rainfall record were available for Aldabra before the Royal Society began recording in 1967 (Table 9). The complete years gave a mean annual rainfall of 640 mm, with both 1958 and 1959 having less than 400 mm. Records since 1967 show a variable but substantially greater annual rainfall, with several years in excess of 1000 mm (Table 10). The mean annual rainfall for

the Royal Society period of record is almost exactly 1070 mm, and all records to the end of 1973 give a mean of 940.6 mm. Figures 3 gives histograms for the pre-1967 and post-1967 records and for all data combined. The earlier records showed considerably driers conditions during the Trade Wind months May-August, and also during November-December: during the last few years only the months of September and October have been consistently dry, whereas according to earlier records a comparably dry season had extended for nearly six months of the year.

Figure le gives the sequence of monthly rainfalls since 1967 and Figure 4 the actual monthly totals over the period of record. The former shows great variability in incidence and amount from year to year; the latter demonstrates that whereas the driest months of the Trades are consistently dry, the wet months can be highly variable. The main control of total annual rainfall appears to be the extent to which rainfall during January and February is high (1969, 1973) or is suppressed (1968, 1970), though in 1974 a substantial part of the total fell during March and April. There is no clear correlation between monthly rainfall and other monthly mean characteristics such as temperature, pressure and wind. The highest monthly total so far recorded is 423 mm (March 1950); several months have recorded zero rainfall, but all these records are before 1967. Annual totals vary from 547 mm (1968) to 1467 mm (1974).

Daily rainfall records permit the analysis of daily intensities and frequencies. Table 11 gives the frequency of occurrence of daily rainfalls in 5 mm/day class intervals for 1968-1972. 70 per cent of all rain-days have less than 5 mm rainfall, and 90 per cent less than 15 mm. Three days in five years have recorded more than 100 mm of rain, and the highest daily fall recorded is 165.5 mm on 7 April 1969, almost the same as the 6 inches recorded on 12 January 1891 (Spurs 1892, 48). During 1968-72 rain fell on 38 per cent of the days.

Data on the frequency of daily falls in excess of 10, 25, 50 and 100 mm are given in Table 12. Normally three-quarters of all annual rainfall comes in falls greater than 10 mm/day. There is a close positive correlation between the annual rainfall in any year and the number of days in the year with 10-25 mm/day rainfall (Figure 5); the correlation with higher intensity falls is, however, erratic, presumably because of the brevity of the record.

An important ecological correlate of these rainfall patterns is the duration of wet and dry periods. If wetness is simply defined as a day with recorded rain and dryness a day with no recorded rain, then most wet and dry periods (i.e. sequences of such days) are of short duration (Table 13, Figure 6): only one wet spell and seven dry spells lasted more than 14 days during 1968-72 (though according to earlier records three consecutive months passed without recorded rainfall in 1949). If, however, 5 mm/day is taken as the threshold dividing 'wet' and 'dry' days (Table 14, Figure 6), most wet spells lasted only one

day and virtually all three days or less, whereas there was no less than 30 dry spells lasting more than 14 days, 24 lasting more than 3 weeks, 16 more than 4 weeks, 8 more than 5 weeks, 5 more than 6 weeks, 4 more than 7 weeks, and 2 more than 8 weeks. The longest dry spell so defined lasted 88 days. By contrast the longest wet spell lasted 7 days. These long periods of dry weather, especially during dry years, must have profound ecological consequences.

All these rainfall records come from the station on the leeward side of the Atoll. Farrow (1971) drew attention to the need for comparative data from different parts of Aldabra, to establish local variability, and presented one month's comparison in 1968 between West Island and East Channel. In 1969-70 J. Frazier maintained records for most of the period July 1969 to June 1970 at Dune Jean-Louis on the south coast. It is possible to compare the days for which he has records (221) with Station records (Table 15). The total rainfall at the Station over this period was 70.5 per cent of that at Dune Jean-Louis, and the total number of rain-days at the Station was 69.5 per cent of that at Dune Jean-Louis. The correlation between daily rainfall at the two sites is only 0.35. The mean rainfall per rain-day is, however, very similar (6.33 mm at the Station and 6.24 mm at Dune Jean-Louis), and the higher totals on the south coast clearly arise from rain falling there more frequently than on the leeward coast. These data are, of course, preliminary, and more detailed work on local climatic variability is now being carried out by R. J. Hnatiuk.

These new rainfall data modify the pattern of Indian Ocean rainfall north of Madagascar presented by Stoddart (1971, Figure 2), making the arid zone in the Aldabra area less evident. The Aldabra records are strikingly parallel to those for the Iles Glorieuses to the south, which were also not included in the earlier analysis. Battistini and Cremers (1972, 1) show that the mean annual rainfall for the Iles Glorieuses is almost identical to that for Aldabra over the Royal Society period of record, though the summer period is drier on Aldabra and the onset of the Trades is wetter (Table 16).

Other Data

Daily records of maximum, minimum and dry bulb temperatures, dew point, relative humidity, pressure, wind speed, wind direction, cloud cover and rainfall are available from the Royal Society for the period since October 1967. In addition, daily records are also maintained of visibility, vapour pressure, form and height of cloud, and ground temperature at 1 ft depth, and could be provided on request. It is planned to increase the scope of the recording station to World Weather Watch standards during 1975. The standard Station records will also be extended by additional screen and microclimate records being maintained on a temporary basis in different parts of the atoll during 1973-74.

Acknowledgements

The data recorded here were obtained by volunteers from the Royal Society Expedition to Aldabra 1967-69, and subsequently by the staff of the Royal Society Aldabra Research Station. We thank Dr. J. Frazier for making available his daily rainfall records for Dune Jean-Louis for 1969-70.

References

Battistini, R. and Cremers, G. 1972. Geomorphology and vegetation of Iles Glorieuses. *Atoll Res. Bull.* 159 : 1-10, 7 figs., 19 pl.

Farrow, G. E. 1971. The climate of Aldabra Atoll. *Phil. Trans. Roy. Soc. Lond.* B 260: 67-91, 16 figs.

Spurs, T. J. 1892. Report on Aldabra to T. Risely Griffiths, Esq., Administrator of Seychelles Islands. Port Victoria, Seychelles, July 19, 1891. *Colonial Reports - Annual, No. 40: Mauritius (Seychelles and Rodriguez), Annual Reports for 1889 and 1890, with a report on the island of Aldabra* (London: H.M.S.O.), 46-50.

Stoddart, D. R. 1971. Rainfall on Indian Ocean coral islands. *Atoll Res. Bull.* 147: 1-21, 11 figs.

Table 1. Mean monthly atmospheric pressure at Aldabra, mb

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	1015.0	1012.0	1012.1
1968	1012.9	1012.8	1010.8	1012.2	1014.0	1015.7	1017.1	1017.3	1016.0	1014.8	1013.4	1011.6
1969	-	-	-	-	-	-	-	-	-	-	1013.7	1013.1
1970	1012.2	1011.6	1011.2	1012.9	1013.8	1016.6	1017.6	1016.4	1015.8	1015.4	1013.9	1012.8
1971	1012.2	1010.4	1012.4	1011.8	1013.8	1016.8	1016.2	1016.6	1016.6	1016.3	1013.9	1012.0
1972	1011.0	1010.4	1011.7	1012.2	1013.8	1015.1	1017.1	1016.4	1016.3	1014.8	1013.2	1013.2
1973	1012.3	1011.4	1012.2	1012.4	1013.8	1016.1	1016.7	1017.5	1016.4	1015.2	1015.4	1014.2
1974	1013.0	1012.1	1013.1	1012.9	1015.1	1016.4	1018.1	1017.9	1017.8	1016.5	1015.2	1013.2

Table 2. Mean monthly wind speed, kts

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	6.4	4.1	5.2
1968	5.8	5.1	5.5	6.3	6.8	9.3	9.3	12.4	14.4	12.1	11.1	5.9
1969	4.9	5.2	4.3	3.7	7.0	7.8	10.2	13.0	9.1	7.5	6.3	5.1
1970	6.4	7.3	4.5	5.8	7.7	7.6	5.7	5.9	7.9	7.7	5.2	4.2
1971	6.5	16.6	19.5	7.3	10.6	10.3	13.4	12.1	10.9	10.5	4.5	4.9
1972	5.0	10.1	5.8	10.0	11.9	12.4	14.4	14.2	17.3	15.1	8.9	5.2
1973	10.1	6.7	7.2	6.4	8.2	8.5	7.1	8.0	7.1	7.2	4.2	3.6
1974	2.5	3.4	3.7	6.1	5.5	4.7	6.3	6.5	6.8	5.1	2.9	2.0

Table 3. Number of occurrences of calms and winds in excess of 10 and 20 kts, 1967-74

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1967	Calm	-	-	-	-	-	-	-	-	-	0	0	1	-
	>10 kts	-	-	-	-	-	-	-	-	-	3	0	2	-
	>20 kts	-	-	-	-	-	-	-	-	-	2	0	0	-
1968	Calm	0	0	2	0	0	0	0	0	1	0	0	0	3
	>10 kts	5	0	2	4	7	11	12	20	22	18	15	5	111
	>20 kts	0	0	0	0	0	1	1	0	4	0	2	2	10
1969	Calm	3	1	2	1	1	0	0	0	0	0	0	0	8
	>10 kts	3	4	1	1	7	8	11	15	8	3	1	0	62
	>20 kts	0	0	0	0	0	0	0	9	0	0	0	0	9
1970	Calm	0	1	1	0	1	0	1	0	0	1	0	3	8
	>10 kts	0	6	1	0	3	7	0	2	10	9	1	1	40
	>20 kts	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	Calm	4	3	3	2	0	1	0	0	0	0	3	2	18
	>10 kts	10	12	18	9	20	16	25	23	21	22	3	2	181
	>20 kts	1	1	1	0	0	0	1	0	0	0	0	1	5
1972	Calm	2	0	1	0	0	0	0	0	0	0	1	1	5
	>10 kts	5	18	6	18	21	22	27	24	27	25	10	3	206
	>20 kts	0	0	1	2	3	1	3	4	10	8	1	0	33
1973	Calm	1	4	1	0	0	0	0	0	0	0	0	4	10
	>10 kts	13	6	4	3	11	12	6	11	9	7	0	3	85
	>20 kts	3	2	0	0	0	1	0	0	0	0	0	0	6
1974	Calm	0	0	0	0	0	1	0	1	0	0	0	2	4
	>10 kts	0	1	0	5	7	5	7	4	6	2	0	0	37
	>20 kts	0	0	0	1	0	0	0	0	0	0	0	0	1

Table 4. Maximum wind speeds recorded in each month, 1967-1974 (kts)

(Figures in brackets are number of days on which the given speed was recorded)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	24 (1)	9 (1)	13 (2)
1968	19 (1)	9 (5)	13 (2)	13 (4)	13 (7)	24 (1)	24 (1)	19 (5)	44 (1)	19 (6)	27 (1)	25 (1)
1969	19 (1)	13 (3)	14 (1)	13 (1)	13 (7)	19 (1)	19 (4)	24 (3)	19 (3)	13 (3)	13 (1)	9 (8)
1970	9 (13)	13 (6)	13 (1)	9 (8)	13 (3)	13 (7)	9 (12)	13 (2)	12 (1)	13 (1)	13 (1)	12 (1)
1971	30 (1)	20 (1)	20 (1)	12 (2)	18 (3)	19 (1)	20 (1)	19 (2)	16 (2)	18 (1)	12 (1)	35 (1)
1972	18 (1)	18 (1)	30 (1)	20 (2)	25 (1)	28 (1)	25 (1)	23 (2)	35 (1)	25 (5)	20 (1)	12 (2)
1973	24 (3)	24 (2)	19 (2)	10 (3)	12 (7)	20 (1)	12 (2)	14 (1)	12 (4)	14 (1)	8 (2)	13 (1)
1974	6 (2)	10 (1)	8 (4)	22 (1)	12 (2)	12 (1)	16 (1)	14 (1)	11 (1)	10 (2)	6 (2)	5 (2)

Table 5. Highest maximum temperatures in each month at Aldabra

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	-	33.4	34.0
1968	36.3	36.0	32.9	32.9	31.3	30.6	29.1	28.5	30.6	30.7	31.2	33.0
1969	33.5	33.0	34.0	33.0	32.0	30.0	28.7	28.7	29.4	29.7[1]	-	-
1970	-	-	-	32.5	31.5	29.5	29.0	29.0	30.0	30.5	32.0	34.8
1971	32.4	31.4	31.4	33.8	30.1	28.4	27.4	27.4	27.8	30.2	31.8	32.3
1972	31.6	32.3	32.2	32.0	31.2	30.0	28.8	28.9	29.9	31.2	32.4	32.6
1973	35.9	32.3	33.2	32.5	33.6	30.0	28.9	31.7	29.8	32.2	32.5	32.4
1974	32.3	33.1	33.0	31.6	31.1	30.0	28.8	28.5	29.3	30.6	32.1	33.0

[1].4 days record only

Table 6. Mean maximum monthly temperatures at Aldabra

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	-	30.81	32.04
1968	31.64	32.09	31.14	31.27	30.18	28.94	27.49	27.86	28.81	29.89	30.35	31.11
1969	31.61	31.60	32.05	31.63	30.59	28.77	27.98	27.57	28.33	29.48[1]	-	-
1970	-	-	-	31.37	30.08	28.83	28.35	28.31	28.54	29.46	30.52	31.31
1971	30.71	30.31	30.28	30.45	29.08	27.18	26.81	26.69	27.07	28.07	30.15	30.95
1972	30.23	31.07	30.67	30.91	30.19	27.89	27.50	28.08	28.50	29.75	30.64	30.97
1973	31.06	30.57	31.40	31.33	30.08	28.49	27.50	28.00	28.58	29.62	31.13	30.85
1974	29.80	30.97	31.03	30.19	30.03	28.59	27.68	27.22	28.13	29.40	30.91	31.53
Mean	30.84	31.10	31.10	31.02	30.03	28.38	27.62	27.68	28.28	29.36	30.64	31.24

1 4 days of record only: disregarded in mean

Table 7. Mean minimum monthly temperatures at Aldabra

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	-	24.38	25.67
1968	24.91	25.59	24.68	24.35	23.77	23.09	21.86	22.01	22.59	23.46	24.07	24.40
1969	24.30	25.72	25.49	24.92	25.08	23.49	22.45	21.84	21.85	23.55	24.46	24.53
1970	26.08	26.02	26.11	25.26	24.52	23.36	23.26	21.89	22.10	22.93	23.98	24.66
1971	24.82	25.40	24.73	25.13	24.67	22.70	22.43	21.85	22.35	23.26	23.84	24.19
1972	24.50	25.98	24.75	25.13	25.22	23.82	22.94	22.85	23.61	24.52	25.50	24.28
1973	25.87	25.99	26.36	25.86	25.03	23.62	22.86	22.45	22.91	23.98	24.42	24.26
1974	24.15	24.71	24.59	24.92	24.75	23.35	22.42	22.14	22.61	23.50	24.37	24.48
Mean	24.95	25.63	25.24	25.08	24.72	23.35	22.60	22.15	22.57	23.60	24.38	24.56

Table 8. Lowest minimum temperatures in each month at Aldabra

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967	-	-	-	-	-	-	-	-	-	-	22.5	23.0
1968	21.6	22.8	23.1	22.0	21.3	19.5	20.2	19.6	21.2	22.0	22.8	22.4
1969	22.7	23.0	23.0	23.5	22.5	17.5	20.6	19.5	17.9	22.2	22.3	21.6
1970	22.6	23.0	23.7	22.8	22.0	21.0	20.5	20.0	20.0	21.5	22.2	23.0
1971	22.2	21.3	21.5	23.0	22.6	20.1	20.7	18.8	21.0	22.0	21.8	22.0
1972	22.4	23.6	21.9	21.9	22.8	21.0	21.8	21.5	22.4	23.5	23.6	22.8
1973	21.4	23.8	24.0	23.9	23.5	22.2	21.3	20.2	21.1	22.8	23.4	22.7
1974	22.3	22.8	22.8	22.4	22.4	21.1	20.3	19.8	20.9	22.0	22.6	22.0

Table 9. Aldabra rainfall records before 1967: monthly totals in mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1949	-	-	-	-	-	2	26	0	0	0	13	57	-
1950	95	219	423	272	6	24	0	16	37	10	23	67	1192
1951	92	60	-	221	46	-	13	32	0	7	70	-	-
1952	160	306	29	250	13	18	4	0	-	-	-	-	-
1953	-	-	54	67	30	38	-	-	-	-	-	-	-
1958	92	101	40	36	2	2	9	8	4	2	45	40	381
1959	102	199	6	1	0	1	1	4	4	0	19	12	349
Mean	108	177	110	141	16	14	9	10	9	4	34	44	640

Table 10. Aldabra rainfall records 1967-1974: monthly totals in mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1967	-	-	-	-	-	-	-	-	-	2.7	147.2	5.4	-
1968	11.9	28.0	133.0	72.4	21.0	38.0	69.5	14.8	9.7	7.3	56.5	85.0	547.1
1969	153.4	147.2	151.5	393.5	176.3	36.8	38.7	14.3	18.5	11.8	54.9	56.8	1253.7
1970	47.5	85.2	139.6	210.5	31.7	29.5	33.7	25.7	7.3	20.9	12.7	56.0	700.3
1971	244.5	57.4	285.9	192.5	34.7	65.9	14.3	19.1	8.6	6.0	89.6	201.8	1220.3
1972	224.5	15.0	112.2	162.2	28.2	100.3	54.6	75.1	4.2	12.7	25.6	240.2	1054.8
1973	261.0	286.8	262.8	56.7	57.1	47.7	81.3	25.2	21.8	33.7	9.2	77.6	1220.9
1974	290.6	114.5	380.8	346.4	50.4	29.4	52.2	31.8	1.9	1.1	19.4	148.9	1467.4
Mean[1]	176.2	104.9	209.4	204.9	57.1	49.7	49.2	29.4	10.3	12.0	51.9	109.0	1066.4
Mean[2]	108	177	110	141	16	14	9	10	9	4	34	44	640
Mean[3]	147.9	134.9	168.2	175.5	38.2	33.3	30.6	20.4	9.8	8.9	46.5	87.3	940.6
Years[4]	12	12	12	13	13	13	13	13	12	13	13	12	11

[1] 1967-1974; [2] 1949-1959 (incomplete records); [3] All records 1949-1974; [4] All records

Table 11. Frequency of daily rainfalls at Aldabra Atoll, 1968-1972

Daily rainfall, mm	Number of days	Percent total number of raindays
0.1 - 5	487	70.38
6 - 10	86	12.43
11 - 15	43	6.21
16 - 20	14	2.02
21 - 25	15	2.31
26 - 30	8	1.16
31 - 35	6	0.87
36 - 40	11	1.59
41 - 45	4	0.58
46 - 50	3	0.43
51 - 55	4	0.58
56 - 60	4	0.58
61 - 65	1	0.14
66 - 70	2	0.29
71 - 75	0	0
76 - 80	0	0
81 - 85	0	0
86 - 90	0	0
91 - 95	0	0
96 - 100	1	0.14
>100	2	0.29

Table 12. Rainfalls occurring in intensities exceeding 10, 25, 50 and 100 mm/day, 1968-1973

Year	Annual rainfall mm		>10 mm/day	>25 mm/day	>50 mm/day	>100 mm/day
1968	547.1	Total amount, mm	255.4	117.7	51.0	0
		% annual total	46.5	21.4	9.3	0
		Number of days	12	3	1	0
1969	1253.7	Total amount, mm	920.7	603.8	234.5	164.5
		% annual total	73.4	48.2	18.7	13.1
		Number of days	33	13	2	1
1970	700.3	Total amount, mm	416.8	231.8	152.8	101.4
		% annual total	59.5	33.0	21.8	14.5
		Number of days	14	7	2	1
1971	1220.3	Total amount, mm	894.2	535.0	387.3	100.0
		% annual total	73.3	43.8	31.7	8.2
		Number of days	32	10	4	1
1972	1054.8	Total amount, mm	783.8	564.6	170.0	0
		% annual total	74.3	53.5	16.1	0
		Number of days	29	14	3	0
1973	1220.9	Total amount, mm	936.7	549.2	439.9	236.5
		% annual total	76.7	45.0	36.0	19.4
		Number of days	32	9	5	2

Table 13. Duration of wet (rain recorded) and dry (no rain) spells at Aldabra, 1968-1972

Duration of spell days	Number of occurrences Wet	Dry
1	164	122
2	69	60
3	32	39
4	19	29
5	22	16
6	3	13
7	3	11
8	5	5
9	3	4
10	1	3
11	-	6
12	-	3
13	1	2
14	-	2
15	-	1
16	-	1
17	-	1
18	-	1
19	1	-
20	-	-
21	-	1
22	-	-
23	-	1
24	-	1

Table 14. Duration of wet (more than 5mm/day) and dry (less than 5mm/day) spells at Aldabra, 1968-1972

Duration of spell days	Number of occurrences Wet	Number of occurrences Dry
1	127	44
2	30	18
3	13	14
4	1	15
5	-	15
6	-	6
7	1	5
8	-	6
9	-	3
10	-	3
11	-	6
12	-	4
13	-	3
14	-	1
15	-	1
16	-	1
17	-	1
18	-	1
20	-	1
21	-	1
22	-	2
23	-	2
25	-	1
27	-	2
28	-	1
30	-	4
34	-	1
35	-	3
37	-	1
41	-	1
43	-	1
48	-	1
50	-	1
55	-	1
64	-	1
88	-	1

Table 15. Local variability of Aldabra rainfall, 1969-70 (West Island and Dune Jean-Louis)

Year	Month	Number of days of record at both stations	Total rainfall Dune Jean-Louis mm	Total rainfall West Island mm	Number of raindays Dune Jean-Louis	Number of raindays West Island
1969	Jul	31	23.78	38.70	17	13
	Aug	19	7.73	7.32	8	6
	Sep	15	10.30	18.30	6	5
	Oct	7	2.06	0	4	0
	Nov	28	25.11	54.90	16	14
1970	Jan	31	119.73	47.50	11	7
	Feb	24	124.62	85.20	19	11
	Mar	19	240.70	78.70	9	8
	Apr	30	197.68	210.50	23	16
	May	15	38.64	18.80	13	8
	Jun	2	8.61	3.20	2	1
Totals		221	798.96	563.12	128	89

*Dune Jean-Louis records by J. Frazier

Table 16. Mean monthly rainfall at Aldabra and at Iles Glorieuses

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Aldabra[1]	157	103	181	181	58	53	44	29	12	14	57	103	1000
Assumption[2]	164	96	126	169	45	31	32	39	6	6	39	95	867
Iles Glorieuses[3]	206	153	152	96	84	68	39	60	11	5	20	119	1012

[1] 1968-1973

[2] 1964-1967 (Stoddart 1971)

[3] Ten year averages: Battistini and Cremers (1972)

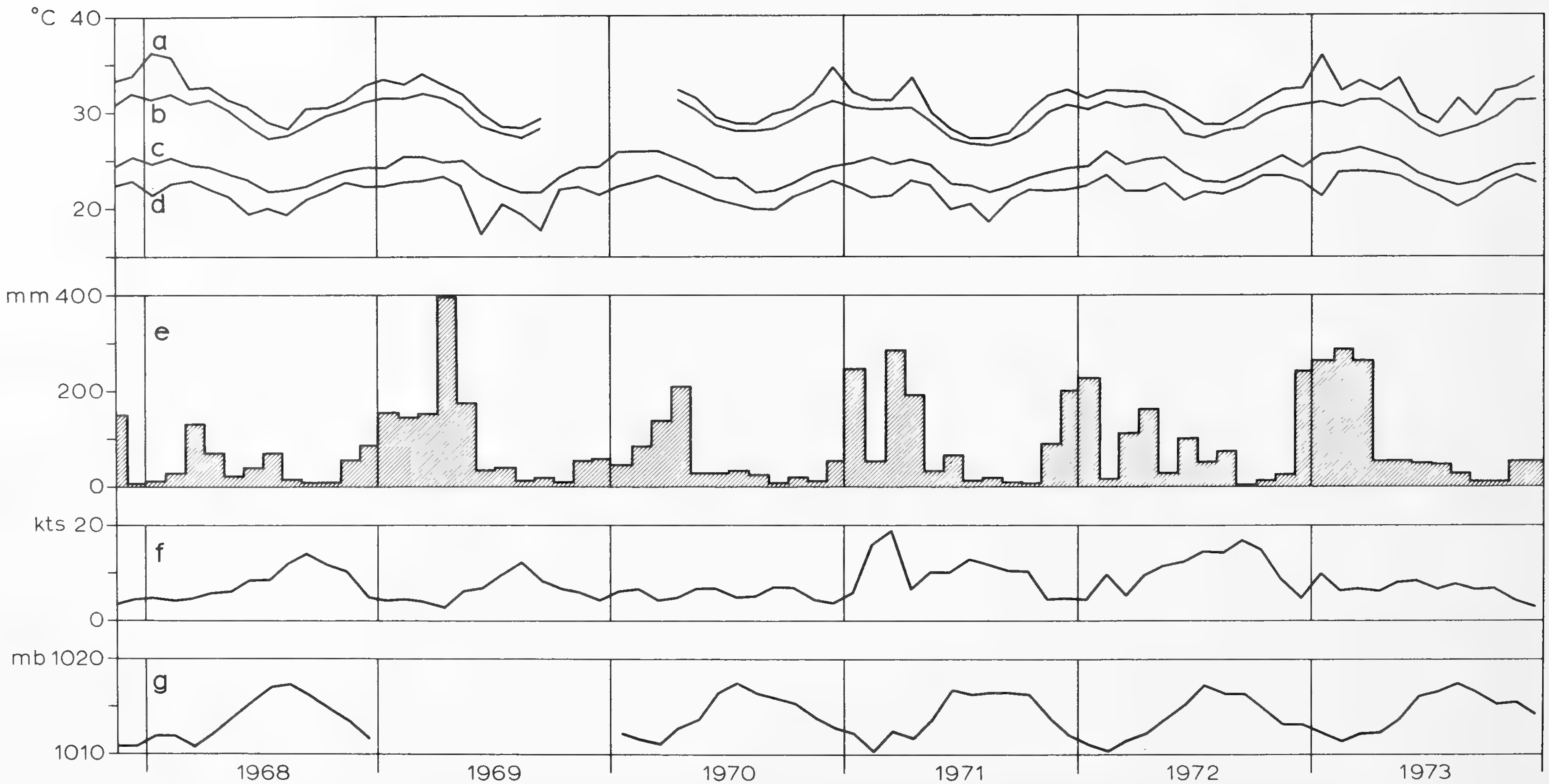


Fig. 1 Records at Aldabra of (a) absolute maximum monthly temperature, (b) mean maximum monthly temperature, (c) mean minimum monthly temperature, (d) absolute minimum monthly temperature, (e) monthly rainfall, (f) mean monthly wind speed, and (g) mean monthly atmospheric pressure, 1967-1973.

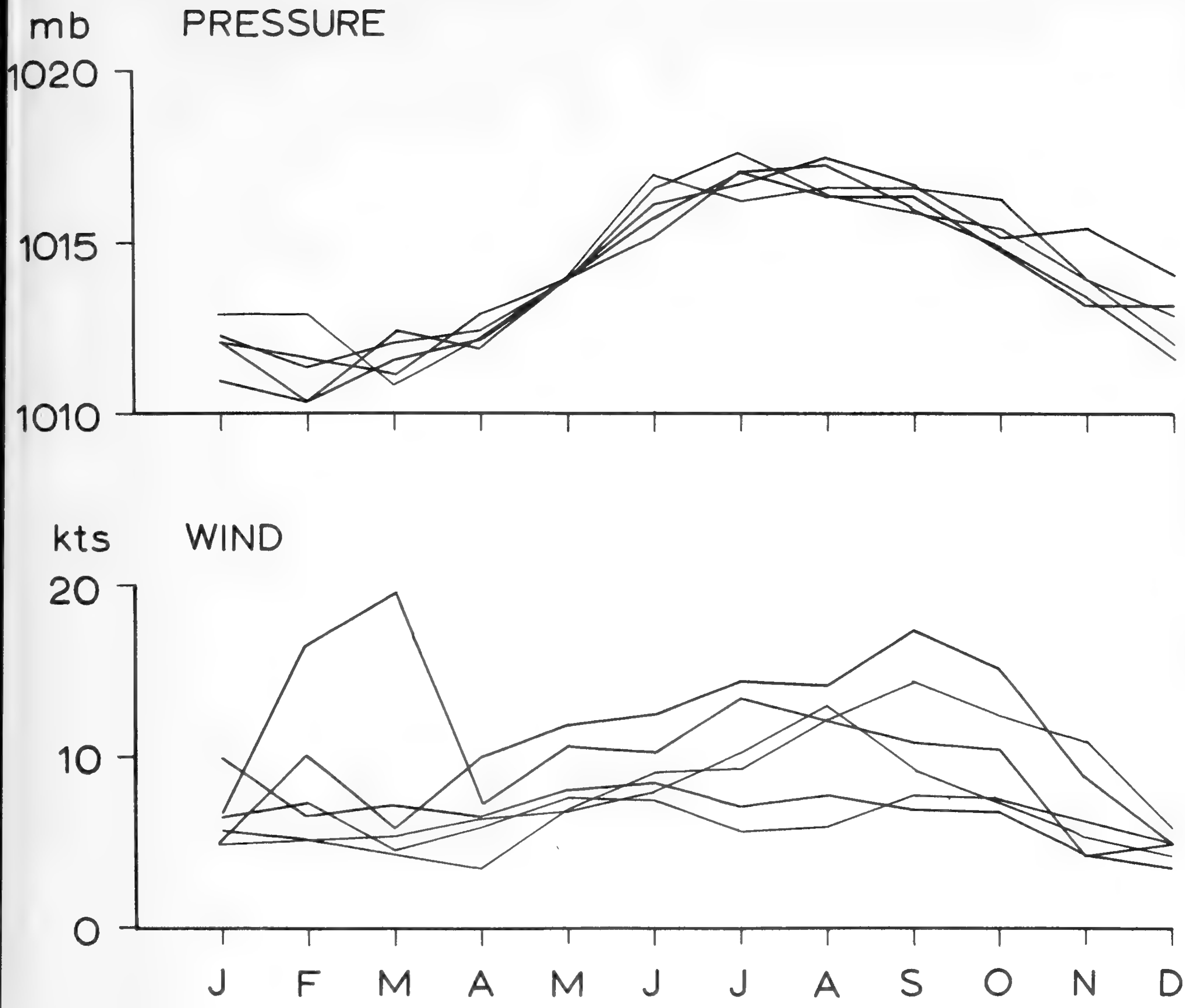


Fig. 2 Annual records of (a) mean monthly wind speed and (b) mean monthly atmospheric pressure at Aldabra, 1968-1973.

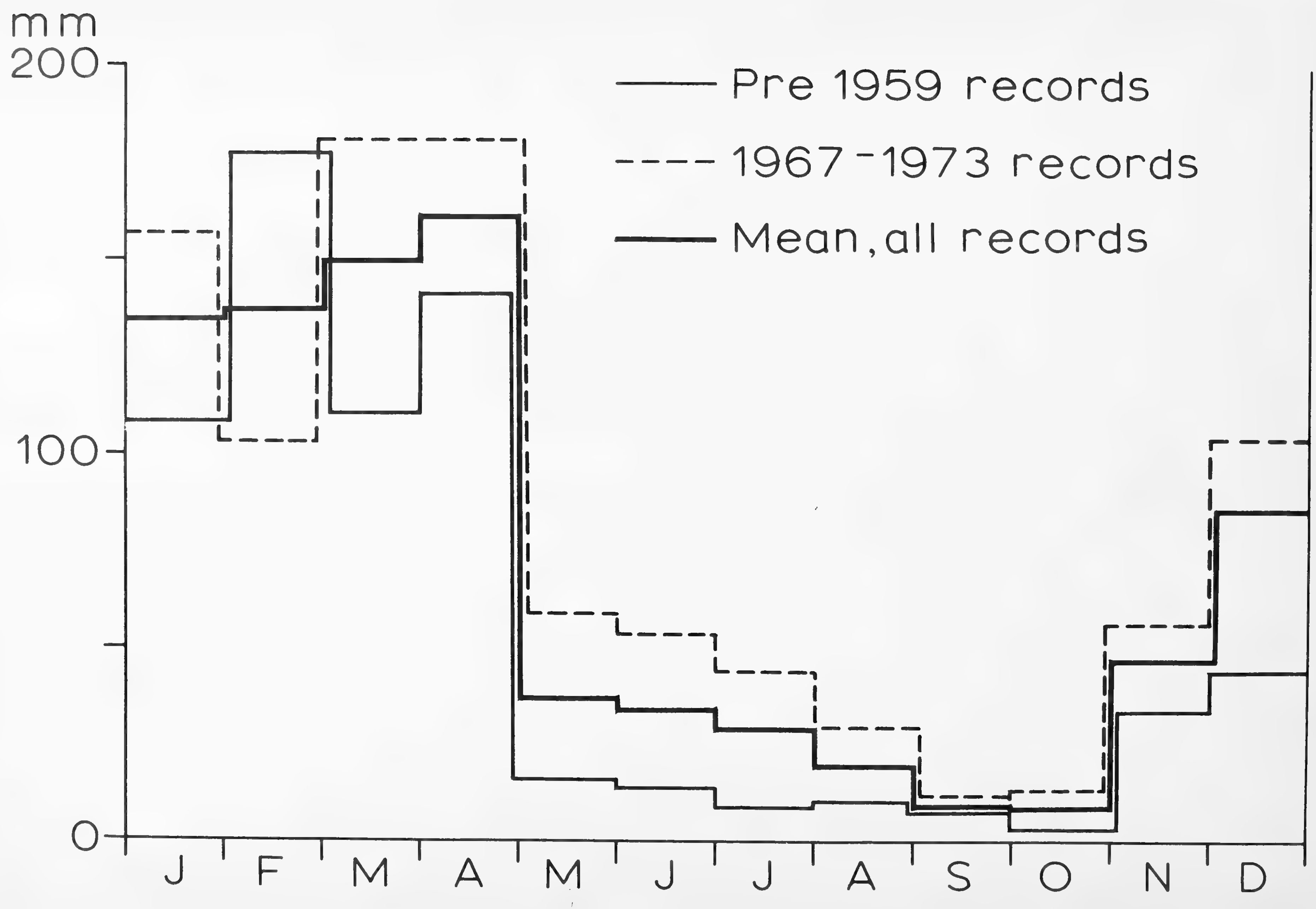


Fig. 3 Mean monthly rainfall at Aldabra based on pre-1959 records, 1967-1973 records, and all available data.

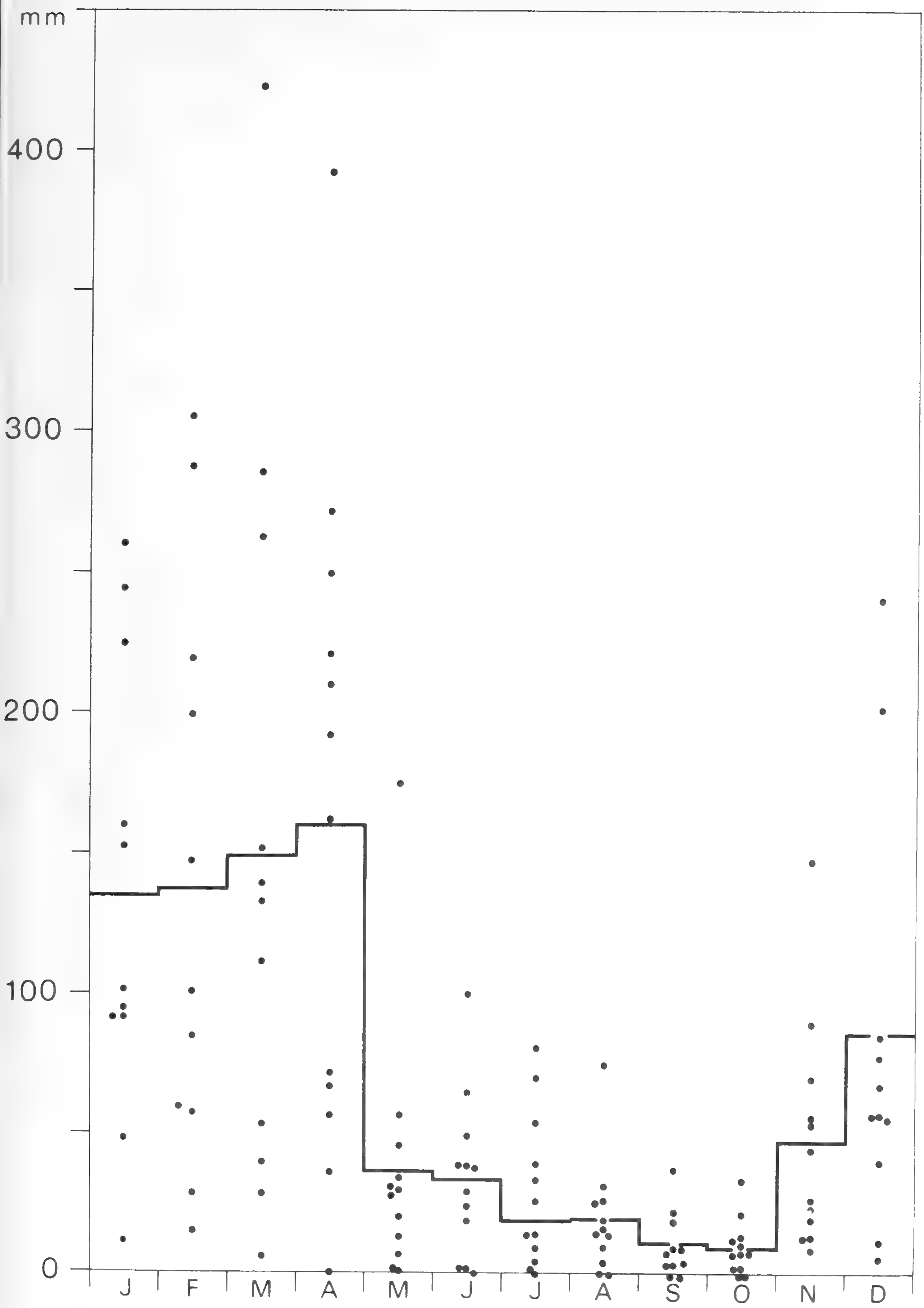


Fig. 4 Monthly rainfall records and mean monthly rainfall for Aldabra, all available records.

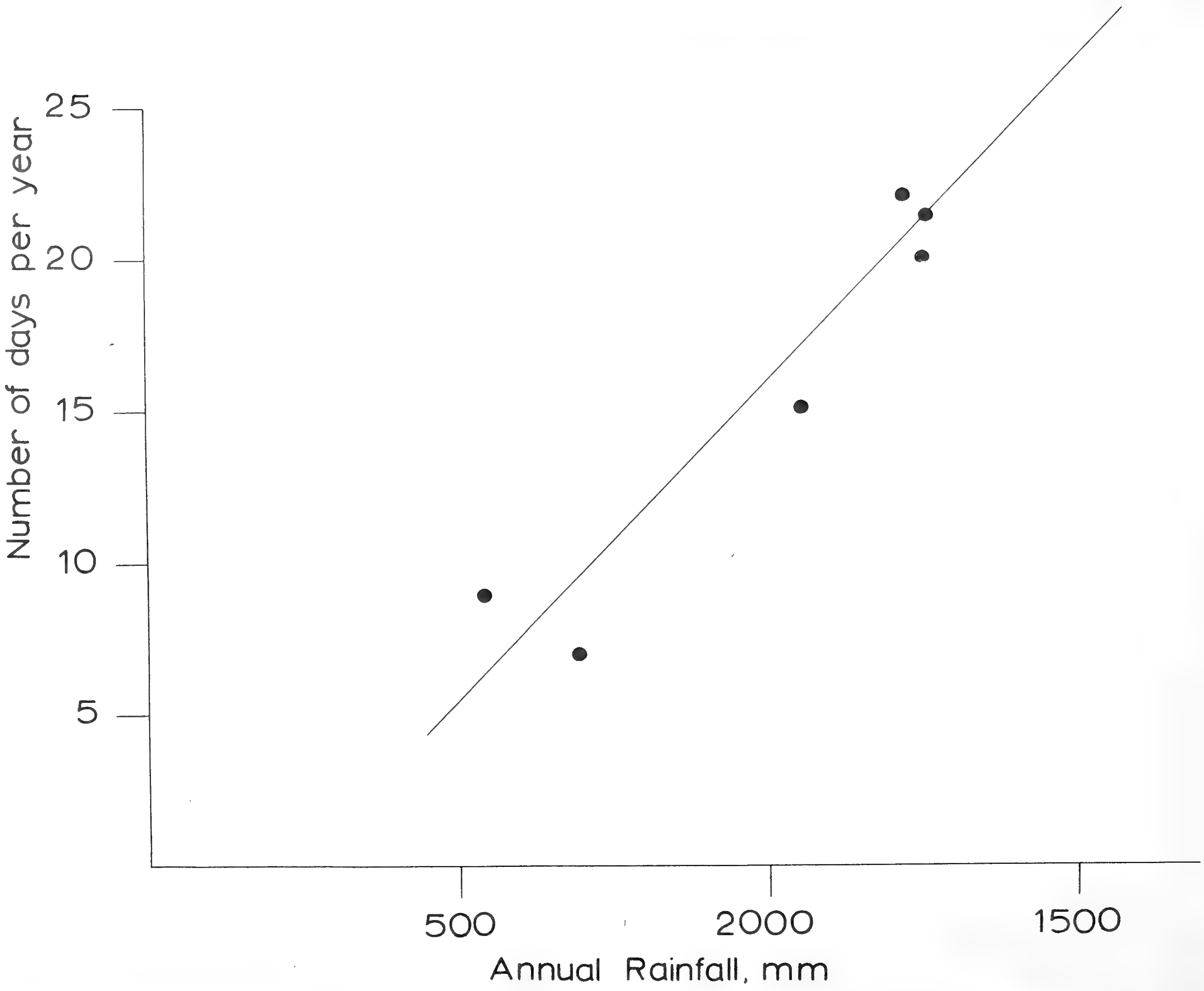
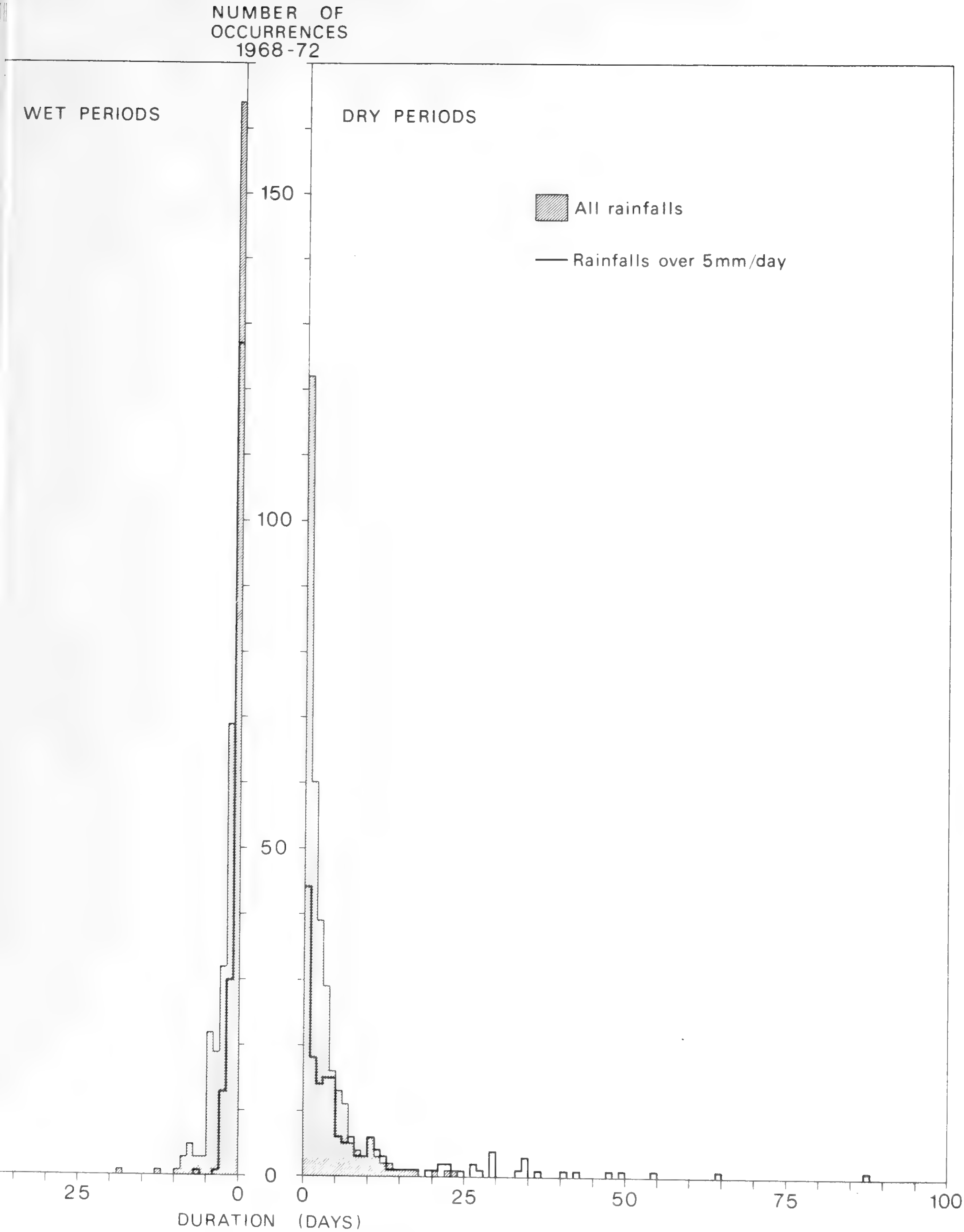


Fig. 5 - Relationship between annual rainfall and number of days in the year with rainfalls of 10-25 mm, 1968-1973.



ig. 6 Frequency and duration of wet and dry periods at Aldabra, 1968-1972.

ATOLL RESEARCH BULLETIN

NO. 203.

ANNOTATED CHECK LIST OF CORALS IN THE MASCARENE ARCHIPELAGO, INDIAN OCEAN

by Gérard Faure

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

ANNOTATED CHECK LIST OF CORALS IN THE MASCARENE ARCHIPELAGO, INDIAN OCEAN

by

Gérard Faure[1]

Summary

1500 samples of corals have been collected by the author since 1969, in the different reef communities of the Mascarene archipelago, from 0 to 50 meters by scuba diving. A total of 135 species (including 6 species of non-scleractinian corals, belonging to 58 genera (including the genera, *Millepora, Heliopora, Distichopora*) known to date are listed in this paper.

Variations in the distribution of genera and species between the three islands can be attributed primarily to a more or less great diversity in the biota of the islands, and secondarily to the disparity in the present status of our knowledge of the different islands.

Introduction

The Mascarene archipelago is situated in the western Indian ocean about 700 km, to the east of Madagascar, in the longitudes 55°23' - 63°20' and latitudes 21°7' - 19°40'. It is composed of three volcanic islands: Réunion, Mauritius, Rodriguez which form geologically topographical units.

General Mascarene reef studies have been carried out by : Gardiner (1936), Baissac and *al*. (1962), Pichon (1967, 1971), Faure and Montaggioni (1970, 1971 a, 1971 b, 1974), Faure (1973, 1974), Montaggioni (1970, 1973).

There are many papers dealing with the systematics of corals in the Mascarene archipelago (see references), specially in Mauritius, but most of them are old and incomplete, except those of Michel (1974), Stoddart (1970), for Mauritius; Brüggemann (1879) for Rodriguez, and

---

[1] Station Marine d'Endoume, Marseille; Centre Universitaire, St. Denis, Réunion.
(Manuscript received June 1975 --Eds.)

Rosen (1971) for the three islands. The present is intended to serve as a first annotated list of the corals of the Mascarene archipelago.

Class ANTHOZOA Ehrenberg, 1834
Subclass HEXACORALLIA Haeckel, 1896
Order SCLERACTINIA Bourne, 1900
Suborder ASTROCOENIINA Vaughan and Wells, 1943
Family THAMNASTERIDAE Vaughan and Wells, 1943

Genus *Psammocora* Dana, 1846
Subgenus *Psammocora* Dana, 1846

Psammocora (Psammocora) contigua Esper : Reunion, Mauritius, Rodriguez
common : Inner reef, lagoon coral formations, reef pool, inner reef, passe (0 - 5 m).
Recorded from Mauritius : Crossland (1952)

Psammocora (Psammocora) nierstraszi Van Der Horst : Reunion (uncommon), Mauritius (rare) base of spurs and grooves zone, volcanic flagstone (- 15 - 30 m).

Psammocora (Psammocora) explanulata Van der Horst : Reunion
sporadic : Outer slope (base of grooves and overhanging sidewall) (10 - 25 m).

Subgenus *Plesioseris* Duncan, 1884

Psammocora (Plesioseris) haimiana Milne-Edwards and Haime : Reunion, Mauritius
sporadic : Outer slope (spurs and grooves zone 0- 5 m), reef front, outer reef flat, furrow and outfall.
Recorded from Mauritius : Ortmann (1888), Stoddart (1970), Michel (1974).
Other species recorded from Mauritius : *P. folium* Umbgrove, *P. planipora* Milne-Edwards and Haime, (Michel, 1974); *P. profondicella* Gardiner, Crossland (1948) *P. Vaughani* Yabe and Eguchi, (Michel, 1974; Stoddart, 1970).

Family POCILLOPORIDAE Gray, 1842

Genus *Seriatopora* Lamarck, 1816

Seriatopora hystrix Dana : Mauritius
common : reef pool, inner slope, inner reef slope, 0 - 10 m, outer slope (rare, - 30 m).

Seriatopora angulata Klunzinger : Mauritius :
sporadic : Inner slope, reef pool, inner creek, 0 - 10 m.
Recorded from Mauritius : Ortmann (1888), Stoddart (1970), Michel (1974).
Other species recorded from Mauritius : *S. stellata* Quelch (Stoddart, 1970; Michel, 1974); *S. caliendrum* Ehrenberg (Ortmann, 1888).

Genus *Stylophora* Schweigger, 1819

Stylophora pistillata (Esper) : Mauritius, Reunion, Rodriguez :
abundant : Outer slope (0 - 20 m), reef front, outer and inner reef flats, lagoon coral formations.
Recorded from Mauritius : Stock (1966), Michel (1974).

Stylophora mordax (Dana) : Reunion, Mauritius, Rodriguez :
common : Outer slope (0 - 20 m), reef front, outer reef flat.
Recorded from Rodriguez : Brüggemann (1879), as *S. palmata* Milne-Edwards and Haime.

Stylophora subseriata Ehrenberg : Mauritius :
sporadic : Inner reef, inner reef slope (0 - 20 m).
Recorded from Mauritius : Stock (1966), Michel 1974).

Stylophora sp. Reunion
rare : Outer slope (volcanic flagstone, 25 - 40 m).

Genus *Pocillopora* Lamarck, 1818

Pocillopora brevicornis setchelli Hoffmeister : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (0 - 5 m), reef front.

Pocillopora damicornis (Linnaeus) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope 20 - 40 m.
Recorded from Mauritius : Crossland (1948), Crossland (1952), Stoddart (1970) Michel (1974).
Recorded from Rodriguez : Brüggemann (1879), as *P. favosa* Dana

Pocillopora danae Verrill : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, 0 - 5 m), reef front, outer and inner flats, reef pool.
Recorded from Mauritius : Crossland (1952), Stoddart (1970), Michel (1974).

Pocillopora cespitosa Dana : Reunion, Mauritius, Rodriguez :
common : Outer and inner reef flats, lagoon coral formations, inner slope (0 - 10 m), outer slope (sheltered reefs, 0 - 5 m).

Pocillopora eydouxi Milne-Edwards and Haime : Rodriguez :
rare : Reef front.

Pocillopora verrucosa (Ellis and Solander) : Reunion, Mauritius, Rodriguez :
common : Reef front, outer slope (0 - 30 m).
Recorded from Mauritius : Crossland (1952), Stoddart (1970), Michel (1974).
Recorded from Reunion : Ortmann (1888).
Other species recorded : from Mauritius, *P. damicornis favosa* ?, Stock (1966), Michel (1974); *P. grandis* Dana, Michel (1974); *P. mauritiana* Brüggemann, Brüggemann (1877), Michel (1974); *P. elegans* (Dana), Ortmann (1888).
: from Rodriguez, *P. favosa* Ehrenberg (non *P. favosa* Dana), Brüggemann (1879); *P. grandis* Dana, Brüggemann (1879).
: from Reunion, *P. grandis* Dana, Ortmann (1888).
Other Genus recorded from Mauritius : Genus *Madracis* (Milne-Edwards and Haime, 1849), *M. kauaiensis* Vaughan, Michel, 1974).

Family ASTROCOENIDAE Koby, 1890

Genus *Stylocoeniella* Yabe and Sugiyama, 1935

Stylocoeniella armata Ehrenberg : Reunion, Maritius :
sporadic : Outer slope (10 - 30 m).
Recorded from Mauritius : Wells (1954), as *Astocoenia stylifera* Pourtales.

Family ACROPORIDAE Verrill, 1902

Genus *Acropora* Okey, 1815

Acropora arbuscula (Dana) : Mauritius, Rodriguez
Sporadic : reef pool, lagoon coral formations (0 - 5 m).

Acropora corymbosa (Lamarck) : Reunion, Mauritius, Rodriguez :
common : top of spurs (spurs and grooves zone, 0 - 2 m), reef front.
Recorded from Mauritius : Lamarck (1816), Freycinet (1828), Stoddart (1970), Michel (1974).
from Rodriguez : Brook (1893), Brüggemann (1879), Vaughan (1918), Gravier (1911), Hoffmeister (1925).

Acropora danae (Milne-Edwards and Haime) : Reunion, Mauritius, Rodriguez:
common : Outer slope (spurs and grooves zone, 0 - 10 m).

Acropora humilis (Dana) : Reunion, Mauritius, Rodriguez :
common : Reef front (spur upper platform), outer reef flat.

Acropora hyacinthus (Dana) : Reunion, Mauritius, Rodriguez :
common : Outer slope (0 - 10 m), inner slope (0 - 10 m), reef pool.
Recorded from Mauritius : as *A. cytherea* Dana (= *A. hyacinthus* (Dana), Wells (1954)), by Mobius and *al.* (1880), Ortmann (1888), Michael (1974).
: as *A. arcuata* (Brook) (= *A. hyacinthus* (Dana), Hoffmeister (1925)), by Stoddart (1970), Michel (1974).

Acropora reticulata Brook : Reunion, Mauritius, Rodriguez:
common : Outer slope (sheltered reefs, 0 - 10 m), lagoon coral formations (0 - 2 m).

Acropora pharaonis Milne-Edwards and Haime : Reunion, Mauritius, Rodriguez :
dominant : Outer slope (sheltered reefs,0 - 10 m), inner reef flat, lagoon coral formations, inner slope, reef pool.
Recorded from Mauritius : Stoddart (1970), Michel (1974).
from Rodriguez : Brüggemann (1879).

Acropora hemprichii (Ehrenberg) : Mauritius, Rodriguez :
sporadic : Outer slope (sheltered reefs, 0 - 10 m), channel of the reef flats, reef pool.

Acropora syringodes (Brook) : Reunion, Mauritius, Rodriguez:
Common : Outer slope (base of spurs and grooves zone, volcanic flagstone 18 - 50 m).
Other species recorded from Mauritius : *A. appressa* (Ehrenberg), Michel (1974);

A. baeodactyla (Brüggemann), Stoddart (1970), Michel (1974).
A. cerealis (Dana), Brook (1893), Vaughan (1918), Michel (1974).
A. clathrata (Brook), Brook (1891, 1892), Michel (1974).
A. conccina (Brook), Brook (1891, 1892), Michel (1974).
A. conferta (Brook), Brook (1891, 1892), Michel (1974).
A. erythraea (Klunzinger), Mobius and *al.* (1880).
A. gonagra (Milne-Edwards and Haime), Brüggemann (1877), Michel (1974).
A. grandis (Brook), Stoddart (1970), Michel (1974).
A. gravida Dana, Michel (1974).
A. haimei (Milne-Edwards and Haime), Mobius and *al.* (1880), Michel (1974).
A. irregularis (Brüggemann), Stoddart (1970), Michel (1974).
A. macrostoma (Brook), Brook (1891-1892), Michel (1974).
A. multicaulis (Brook), Stoddart (1970), Michel (1974).
A. kenti (Brook), Stoddart (1970).
A. muricata cervicornis (Lamarck), Mobius and *al.* (1880), Michel (1974).
A. muricata prolifera (Lamarck), Freycinet (1828), Michel (1974).
A. oligocyathus (Brook), Brook (1892, 1893), Michel (1974).
A. polystoma (Brook), Brook (1891, 1893), Michel (1974).
A. pyramidalis (Klunzinger), Mobius and *al.* (1880), Michel (1974).
A. rousseaui (Milne-Edwards and Haime), Michel (1974).
A. seriata (Ehrenberg), Brook (1893), Michel (1974).
A. stigmataria Milne-Edwards and Haime, Michel (1974).
A. symmetrica Brook, Brook (1891), Stoddart (1970), Michel (1974).
A. tuberculosa Milne-Edwards and Haime, Michel (1974).
A. tylostoma Ehrenberg, Brook (1893), Michel (1974).
A. sp, Stoddart (1970).
A. scherzeriana Brüggemann, Klunzinger (1879).

from Rodriguez :

A. alces (Dana), Brüggemann (1879).
A. baeodactyla (Brüggemann), Vaughan (1918).
A. brevicollis Brook, Vaughan (1918).
A. conferta (Quelch), Vaughan (1918), Wells (1954) ?
A. corymbosa (Lamarck), Brüggemann (1879).
A. flabelliformis Milne-Edwards and Haime, Brüggemann (1879).
A. gonagra (Milne-Edwards and Haime), Brüggemann (1879).
A. haimei (Milne-Edwards and Haime), Brüggemann (1879).
A. microclados (Ehrenberg), Brüggemann (1879).
A. plantaginea (Lamarck), Brüggemann (1879).
A. pustulosa (Milne-Edwards and Haime), Brüggemann (1879).
A. seriata (Ehrenberg), Brüggemann (1879).

from Reunion:

A. granulosa Milne-Edwards and Haime, Milne-Edwards and Haime (1860).

Genus *Astreopora* de Blainville, 1830.

Astreopora myriophtalma (Lamarck) : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, volcanic flagstone, 10 - 40 m).
Recorded from Mauritius : Bernard (1896), Michel (1974).

Genus *Montipora* Quoy and Gaimard, 1830.

Montipora edwardsi Bernard : Rodriguez
uncommon : Inner reef flat, lagoon coral formations.

Montipora foliosa (Pallas) : Reunion, Mauritius, Rodriguez.
sporadic : Lagoon coral formations, reef pool, passe, inner slope, outer slope (sheltered reef).
Recorded from Mauritius : Ortmann (1888), Vaughan (1918), Thiel (1932), Crossland (1952), Bernard (1897).

Montipora informis Bernard : Reunion :
rare : Inner reef flat, lagoon coral formations.

Montipora verrucosa (Lamarck) : Reunion, Mauritius.
sporadic : Outer slope (spurs and grooves zone, volcanic flagstone, 12 - 50 m).
Recorded from Mauritius : Ortmann (1888, 1892).

Montipora cf tuberculosa (Lamarck) : Reunion, Mauritius, Rodriguez :
Recorded from Mauritius : Ortmann (1888-1889-1892).
sporadic : Outer slope (spurs and grooves zone), outer and inner reef flats.

Montipora cf millepora Crossland : Mauritius
rare : outer slope (volcanic flagstone - 48 m).
Other species recorded from Mauritius :

M. explanata Brüggemann, Bernard (1897), Brüggemann (1879), Michel (1974).
M. expansa Dana, Ortmann (1888).
M. guppyi Bernard, Stoddart (1970), Michel (1974).
M. lanuginosa Bernard, Bernard (1897), Michel (1974).
M. lobulata Bernard, Bernard (1897), Michel (1974).
M. mammifera Bernard, Michel (1974).
M. rus (Forskål), Ortmann (1888).
M. solanderi Bernard, Bernard (1897), Michel (1974).
M. stylosa (Ehrenberg), Ortmann (1888-1889).
M. undata Bernard, Stoddart (1970), Michel (1974).

From Rodriguez :

M. explanata Brüggemann, Brüggemann (1879), Bernard (1897).
M. divaricata Brüggemann, Brüggemann (1879), Bernard (1897).

M. incrustans Brüggemann, Brüggemann (1879), Bernard (1897).
M. lichen Dana, Brüggemann (1879), Bernard (1897).
M. perforata Bernard, Bernard (1897) = *M. explanata* Brüggemann.
M. solanderi Bernard, Bernard (1897) non *M. foliosa* (Pallas) Brüggemann (1879).

from Mascarene

M. spongodes Bernard, Bernard (1897).
M. subtilis Bernard, Bernard (1897), Wells (1954).

Suborder FUNGIINA Verrill, 1865.
Superfamily AGARICIIDAE Gray, 1847.
Family AGARICIIDAE Gray, 1847.

Genus *Pavona* Lamarck, 1801.
Subgenus *Pavona* Lamarck, 1801.

Pavona (Pavona) cactus (Forskäl) : Reunion, Mauritius, Rodriguez : sporadic : Inner reef flat, reef pool, 0 - 5 m.
Recorded from Mauritius : Michel (1974).

Pavona danai Milne-Edwards and Haime : Reunion, Rodriguez : rare : Inner reef flat, reef pool, 0 - 5 m.

Pavona (Pavona) decussata Dana : Reunion, Mauritius : sporadic : Inner reef flat, reef pool, 0 - 5 m.

Pavona (Pavona) clavus Dana : Reunion, Mauritius, Rodriguez : sporadic : Outer slope, 0 - 30 m (spurs and grooves zone, volcanic flagstone), lagoon coral formations (0 - 5 m).

Pavona (Pavona) divaricata (Lamarck) : Reunion, Mauritius Rodriguez : common : Inner reef flat, reef pool, lagoon reef.

Pavona (Pavona) explanulata (Lamarck) : Reunion, Mauritius, Rodriguez : sporadic : Outer slope (spurs with overhanging sidewall, reef gallery and reef tunnel) - 5 - 30 m.

Pavona (Pavona) variens (Verrill) : Reunion, Mauritius, Rodriguez : common : Outer slope (spurs and grooves zone, 0 - 15 m). Outer and inner reef flat.
Recorded from Mauritius : Ortmann (1889), as *P. repens* Brüggemann.
Other species recorded from Mauritius :

P. cristata Ellis and Solander, Michel (1974) = *P. cactus* (Forskäl).
P. cristata Milne-Edwards and Haime, Michel (1974) = *P. cactus* (Forskäl).
P. frondifera Lamarck, Stoddart (1970), Michel (1974).
P. praetorta Dana, Stoddart (1970), Michel (1974).
P. seriata Brüggemann, Stoddart (1970), Michel (1974).

from Rodriguez :

P. lata Dana, Matthai, 1974.
P. cristata Ellis and Solander, Brüggemann (1879) = *P. cactus* (Forskäl).

Subgenus *Pseudocolumnastraea* Yabe and Sugiyama, 1933.

Pavona (Pseudocolumnastraea) pollicata Wells : Reunion:
rare : Outer slope of sheltered reefs, 5 - 15 m.

Genus *Leptoseris* Milne-Edwards and Haime, 1849.

Leptoseris columna Yabe and Sugiyama : Reunion :
rare : Outer slope (volcanic flagstone, stone and nodule pavement, 35 - 60 m).

Leptoseris hawaiensis Vaughan : Reunion, Mauritius :
rare : Outer slope (volcanic flagstone, stone and nodule pavement, 35 - 60 m).

Leptoseris incrustans (Quelch) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (overhaning sidewall, reef tunnel, reef gallery, volcanic flagstone, 15 - 45 m).

Leptoseris scabra Vaughan : Reunion :
rare : Outer slope (stone and nodule pavement, - 60 m).

Leptoseris sp : Mauritius :
rare : Outer slope (volcanic flagstone, - 45 m).

Genus *Leptoseris* ? Milne-Edwards and Haime

Leptoseris ? mycetoseroide Wells : Reunion, Mauritius :
sporadic : Outer slope (reef tunnel, reef gallery, overhanging sidewall, 15 - 40 m).
Other species recorded from Mauritius : *Leptoseris digitata* Vaughan, Stoddart (1970), Michel (1974).
from Reunion : *Leptoseris fragilis* Milne-Edwards and Haime, Milne-Edwards and Haime (1860)., Matthai (1924).

Genus *Agariciella* Ma,

Agariciella ponderosa Gardiner : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, 10 - 30 m), passe (2 - 10 m).

Genus *Pachyseris* Milne-Edwards and Haime, 1849.

Pachyseris speciosa (Dana) : Reunion, Mauritius, Rodriguez.
common : Outer slope, 10 - 40 m (spurs and grooves zone, volcanic flagstone), passe (2 - 15 m).
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Pachyseris rugosa (Milne-Edwards and Haime) : Reunion :
rare : Outer slope (15 - 40 m).
Other species recorded from Mauritius : *P. laevicollis* (Dana), Michel (1974).

Family SIDERASTREIDAE Vaughan and Wells, 1943.

Genus *Coscinarea* Milne-Edwards and Haime, 1848.

Coscinarea cf. columna Dana : Reunion, Rodriguez :
rare : Outer slope (spurs and grooves zone of sheltered reefs), reef pool, passe.

Coscinarea monile (Forskäl) : Reunion, Mauritius, Rodriguez
common : Outer slope (spurs and grooves zone, volcanic flagstone, 10 - 30 m), passe.
Recorded from Mauritius : Ortmann (1892).

Coscinarea sp. : Mauritius :
rare : Inner reef, - 3 m.

Genus *Horastrea* Pichon, 1971.

Horastrea indica Pichon : Reunion, Mauritius :
sporadic : Outer slope (volcanic flagstone, 15 - 40 m).
Recorded from Reunion : Pichon, 1971.

Superfamily FUNGIICAE Dana, 1846
Family FUNGIIDAE Dana, 1846.

Genus *Cycloseris* Milne-Edwards and Haime, 1849.

Cycloseris cyclolites (Lamarck) : Reunion, Mauritius :
sporadic : Outer slope (base of spurs and grooves zone, and specially volcanic flagstone, 25 - 40 m).
Recorded from Mauritius and Rodriguez : Matthai, (1924).

Genus *Fungia* Lamarck, 1801.

Subgenus *Fungia* Lamarck, 1801.

Fungia (Fungia) fungites (Linnaeus) : Reunion, Mauritius, Rodriguez:
common : (Mauritius and Rodriguez) : Branched coral reef flat, reef pool, inner reef flat, lagoon coral formations, inner slope, 0 - 5 m.
rare : Reunion.
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Subgenus *Danafungia* Wells, 1956.

Fungia (Danafungia) danai Milne-Edwards and Haime : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (0 - 10 m), branched coral reef flat, passe.

Subgenus *Pleuractis* Verrill, 1864.

Fungia (Pleuractis) scutaria Lamarck : Reunion, Mauritius :
common : Outer slope (20 - 40 m).
Recorded from Mauritius : Michel (1974).

Fungia ? somervillei Gardiner : Mauritius :
rare : Outer slope, - 50 m.
Other species recorded from Mauritius : *F. agariciformis* Lamarck, Michel (1974).
F. madagascarensis Vaughan, Stoddart (1970), Michel (1974).
F. patella (Ellis and Solander), Matthai (1924);

F. samboangensis Vaughan,
Stoddart (1970),
Michel (1974).

from Rodriguez:

F. dentigera Leuckart,
Brüggemann (1879);
F. haimei Verrill,
Brüggemann (1879).

Genus *Herpolitha* Eschscholtz, 1826.

Herpolitha limax (Esper) : Reunion, Mauritius, Rodriguez :
common : (Mauritius : Outer slope (sheltered reef, 5 - 15 m), reef pool, lagoon, inner slope (0 - 15 m).
rare (Reunion, Rodriguez) : Outer slope (-20 - 40 m).
Recorded from Mauritius : Matthai (1924), Yabe and Sugiyama (1941), Stoddart (1970), Michel (1974).

Genus *Podabacia* Milne-Edwards and Haime, 1849.

Podabacia crustacea Pallas : Reunion, Mauritius :
rare : Outer and inner reef slopes, passe, 15 - 20 m.

Superfamily PORITICAE Gray, 1842.
Family PORITIDAE Gray, 1842.

Genus *Porites* Link, 1807.

Porites (Porites) somaliensis Gravier : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, volcanic flagstone, 0 - 50 m), reef flat (outer and inner reef flats, micro-atoll zone, lagoon coral formations, reef pool, passe, 0 - 20 m.
Recorded from Mauritius : Michel (1974).

Porites (Porites) solida (Forskäl) : Reunion, Mauritius, Rodriguez:
common : Outer slope (spurs and grooves zone, volcanic flagstone, 0 - 40 m., reef flat, lagoon coral formations, reef pool, 0 - 15 m.
Recorded from Mauritius : Ortmann (1892, 1888), Stoddart (1970)., Crossland (1948), Michel (1974).

Porites (Porites) pukoensis Vaughan : Reunion, Rodriguez :
rare : Reef flat with scattered coral growth.

Porites (Porites) nigrescens Dana : Reunion, Mauritius :
sporadic : Lagoon coral formations, reef pool, passe, outer slope (sheltered reefs, 0 - 10 m).

Porites (Porites) andrewsi Vaughan : Mauritius
rare : Lagoon coral formations, outer slope (- 45 m).
Other species recorded from Mauritius :
P. columnaris Klunzinger, Ortmann (1888).
P. lichen Dana, Stoddart (1970), Michel (1974).
P. lobata Dana, Stoddart (1970), Michel (1974).
P. lutea Milne-Edwards and Haime, Stoddart (1970), Michel (1974).

P. mauritiensis prima Bernard, Bernard (1905), Michel (1974).
P. mauritiensis secunda Bernard, Bernard (1905), Michel (1974).
P. mauritiensis quarta Bernard, Bernard (1905), Michel (1974).
P. mauritiensis quinta Bernard, Bernard (1905), Michel (1974).

Recorded from Rodriguez:
P. arenosa (Esper), Brüggemann (1879) = *P. rodericensis secunda* Bernard, Bernard, (1905), Crossland (1948).
P. lutea Milne-Edwards and Haime, Brüggemann 1879 = *P. rodericensis prima* Bernard, Bernard, (1905).

from Reunion :
P. arenosa (Esper), Milne-Edwards and Haime (1860).

Subgenus *Synarea* Verrill, 1864.

Porites (Synarea) iwayamaensis Eguchi : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone of sheltered reefs, 0 - 25 m), passe, inner reef flat, microatoll zone, reef pool.

Porites (Synarea) cf. danae Milne-Edwards and Haime : Reunion, Mauritus, Rodriguez :
sporadic : Lagoon coral formations, microatoll zone.
Recorded from Mauritius : Ortmann (1888), Michel (1974).

Genus *Goniopora* Blainville, 1830.

Goniopora lobata Milne-Edwards and Haime : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone of sheltered reefs (0 - 20 m), passe.

Goniopora savigny Milne-Edwards and Haime : Reunion :
uncommon : Outer slope (spurs and grooves zone of sheltered reefs, - 15 m), lagoon (0 - 2 m).
Recorded from Mauritius : Michel (1974).

Goniopora cf somaliensis Vaughan : Reunion :
rare : Outer slope, - 15 m.

Goniopora tenuidens Quelch : Reunion, Mauritius :
rare : Outer slope (spurs and grooves zone, 5 - 15 m).
Other species recorded from Mauritius : *G. mauritiensis prima* Bernard, Bernard (1903), Michel (1974).

Genus *Alveopora* Blainville, 1830.

Alveopora cf mortenseni Crossland : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone of sheltered reefs, 0 - 20 m), passe.
Recorded from Mauritius : Crossland (1952).

Alveopora sp : Reunion, Mauritius :
rare : Outer slope (volcanic flagstone, 25 - 40 m).
Other species recorded from Mauritius
A. daedala Blainville, Ortmann (1888), Michel (1974).
A. retepora Blainville, Ortmann (1888), Michel (1974).
A. verilliana Dana = *A. daedala* Blainville, Stoddart (1970), Michel (1974).
A. octoformis Blainville, Ortmann (1888).

Suborder FAVIINA Vaughan and Wells, 1943.
Superfamily FAVIICAE Gregory, 1900.
Family FAVIIDAE Gregory, 1900.
Subfamily FAVIINAE Gregory, 1900.

Genus *Plesiastrea* Milne-Edwards and Haime, 1848.

Plesiastrea versipora Lamarck : Reunion, Mauritius
rare : Outer slope (spurs and grooves zone, 10 - 20 m.).
Recorded from Rodriguez : Brüggemann (1879), as *P. quatrefagesana* Milne-Edwards and Haime, Chevalier (1971).
Other species recorded from Mauritius : *P. peroni* Milne-Edwards and Haime (near *P. versipora* Lamarck), Ortmann (1888).

Genus *Favia* Oken, 1815.

Favia favus (Forskål) : Reunion, Mauritius, Rodriguez :
sporadic : Inner reef flat (reef flat with scattered coral growth), lagoon coral formations, reef pool, inner slope, 0 - 5 m.
Recorded from Mauritius : Ma (1959), Chevalier (1971), Wijsman-Best (1972), Michel (1974).
from Rodriguez : Brüggemann (1879), as *F. denticulata* Ellis and Solander and *F. affinis* Milne-Edwards and Haime.

Favia pallida (Dana) : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, volcanic flagstone, 0 - 40 m), Outer and inner reef flats.

Favia speciosa (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Same repartition as *F. pallida*.
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Favia stelligera (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Reef front, outer slope (spurs and grooves zone, 0 - 10 m).
Recorded from Mauritius : Ortmann (1888), as *F. lobata* Milne-Edwards and Haime, Chevalier (1971).
from Rodriguez : Brüggemann (1879), as *F. lobata* Milne-Edwards and Haime.

Favia laxa (Klunzinger) : Reunion:
rare : Outer slope (0 - 10 m).

Favia cf hombroni (Rousseau) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, 5 - 20 m).

Genus *Favites* Link, 1807.

Favites abdita (Ellis and Solander) : Reunion, Mauritius, Rodriguez :
Sporadic : Outer slope (0 - 40 m), outer and inner reef flats, passe.
Recorded from Mauritius : Ortmann (1888), as *Prionastraea gibbosa* Klunzinger, Ortmann (1892), as *Goniastrea seychellenis*[1] Milne-Edwards and Haime, Crossland (1952), Chevalier (1971).

Favites pentagona (Esper) : Reunion, Mauritius, Rodriguez :
common : Outer slope (0 - 40 m).

Favites vivens (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (0 - 40 m).
Other species recorded from Rodriguez : *Prionastraea rodericana* Brüggemann, Brüggemann (1879); *P. scabra* Brüggemann, Brüggemann (1879).

Genus *Goniastrea* Milne-Edwards and Haime, 1848.

Goniastrea retiformis (Lamarck) : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, 0-15 m), reef front, outer and inner reef flat.
Recorded from Mauritius : Ma (1959), Chevalier (1971), Michel (1974).

Goniastrea pectinata (Ehrenberg) : Reunion, Mauritius, Rodriguez :
abundant : Outer slope (spurs and grooves zone, 0 - 20 m), reef front, outer and inner reef flats, reef pool, passe.
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Goniastrea of incrustans Duncan : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (5 - 30 m).

Genus *Caulastrea* Dana, 1846.

Caulastrea tumida Matthai : Reunion, Mauritius :
sporadic : Outer slope (volcanic flagstone, 25 - 40 m).

Genus *Oulophyllia* Milne-Edwards and Haime, 1848.

Oulophyllia crispa (Lamarck) : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, volcanic flagstone, 10 - 30 m).

Oulophyllia cf aspera Quelch : Mauritius
rare : Outer slope (volcanic flagstone, - 35m).

Genus *Platygyra* Ehrenberg, 1834.

Platygyra daedala (Ellis and Solander) : Reunion, Mauritius, Rodriguez :
abundant : Outer slope (0 - 40 m), reef front, inner and outer reef flats, lagoon coral formations, reef pool, passe.
Recorded from Mauritius : Stoddart (1970), Wijsman-Best (1972), Michel (1974).

---

[1]According to Chevalier (1971), Wijsman-Best (1972).

Recorded from Mauritius and Mascarene islands : Yabe and *al.* (1936).
Recorded from Rodriguez : Matthai 1928, Brüggemann (1879), as *P. esperi* Milne-Edwards and Haime.

Platyggyra lamellina (Ehrenberg) : Reunion, Mauritius, Rodriguez :
sporadic : Inner reef flat, lagoon coral formations, passe, reef pool.
Recorded from Mauritius : Michel (1974).

Genus *Leptoria* Milne-Edwards and Haime, 1848.

Leptoria phrygia (Ellis and Solander) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, 0 - 15 m), reef front, outer and inner reef flats.
Recorded from Mauritius : Matthai (1928), Crossland (1952), Michel (1974).
Other species recorded from Mauritius : *Leptoria gracilis* (Dana), Ortmann (1888), Matthai (1928), Yabe and *al.* (1936).
From Rodriguez : *Leptoria gracilis* (Dana), Brüggemann (1879), as *L. tenuis* Milne-Edwards and Haime, Matthai (1928).

Genus *Hydnophora* Fischer de Waldheim, 1807.

Hydnophora microconos (Lamarck) : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, volcanic flagstone, 0 - 35 m), reef front, Outer and inner reef flats.
Recorded from Rodriguez : Brüggemann (1879).

Hydnophora exesa (Pallas) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, 0 - 15 m), lagoon coral formations, reef pool, passe.
Recorded from Mauritius and Rodriguez : Matthai (1928).
Recorded from Mauritius and Mascarene islands : Yabe and *al.* (1936).

Subfamily MONTASTREINAE Vaughan and Wells, 1943.

Genus *Montastrea*

Montastrea curta (Dana) : Reunion, Mauritius :
rare : Outer slope (spurs and grooves zone, 0 - 15 m), reef front.

Genus *Leptastrea* Milne-Edwards and Haime, 1848.

Leptastrea purpurea (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, 0 - 15 m), reef front, outer and inner reef flats.

Leptastrea transversa (Klunzinger) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves, 0 - 20 m), reef front.

Leptastrea bottae (Milne-Edwards and Haime) : Reunion, Mauritius :
rare : Reef flat with scattered coral growth.
Other species recorded from Mauritius : *L. ehrenbergiana* Milne-Edwards and Haime, Ortmann (1888).

Genus *Cyphastrea* Milne-Edwards and Haime, 1848.

Cyphastrea microphtalma : Reunion, Mauritius, Rodriguez : common : Inner reef flat, lagoon coral formations, 0 - 5 m.

Cyphastrea sairailia (Forskäl) : Reunion, Mauritius, Rodriguez : sporadic : Outer slope (spurs and grooves zone, 0 - 15 m).
Recorded from Mauritius : Ortmann (1888).
Other species recorded from Mauritius : *C. chalcidicum* (Forskäl), Michel (1974).

Genus *Echinopora* Lamarck, 1816.

Echinopora gemmacea (Lamarck) : Reunion, Mauritius, Rodriguez : Abundant : Outer slope (0 - 30 m), outer and inner reef flats, lagoon coral formations, reef pool, passe, 0 - 15 m.
Recorded from Mauritius : Milne-Edwards and Haime (1857), as *E. ehrenbergii* Milne-Edwards and Haime, Ortmann (1888); as *E. ehrenbergii* Milne-Edwards and Haime, Thiel (1932), Michel (1974).
Other species recorded from Mauritius : *E. lamellosa* (Esper), Stock (1966), Michel (1974).
from Rodriguez : *E. spinulosa* Brüggemann, Brüggemann (1879), near *E. gemmacea* Lamarck.

Family ASTRANGIIDAE Verrill, 1869.

Genus *Culicia* Dana, 1846.

Culicia cuticula Klunzinger : Reunion, Mauritius, Rodriguez : uncommon : On the under face of massive and encrusting forms, outer slope (0 - 30 m), reef front, passe.

Family OCULINIDAE Gray, 1847.
Subfamily Galaxeinae Vaughan and Wells, 1943.

Genus *Galaxea* Oken, 1815.

Galaxea fascicularis (Lamarck) : Reunion, Mauritius, Rodriguez : common : Outer slope (0 - 30 m), reef front, outer and inner reef flats, reef pool, passe.
Recorded from Mauritius : Ortmann (1888, 1892), Thiel (1932), Stoddart (1970), Chevalier (1971), Michel (1974).
from Mauritius and Mascarene islands : Yabe and *al.* (1936).
from Rodriguez : Brüggemann (1879), Thiel (1932), Chevalier (1971).
Other species recorded from Mauritius : *G. musicalis* (Linné) = *G. clavus* (Dana), Stoddart (1970), Michel (1974); *G. hexagonalis* Milne-Edwards and Haime, Stoddart (1970), Michel (1974).

Family MUSSIDAE Ortmann, 1890.

Genus *Acanthastrea* (Milne-Edwards and Haime, 1848).

Acanthastrea echinata (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (0 - 30 m), reef pool, passe inner slope, 0 - 15 m.
Other species from Rodriguez : *A. angulosa* Brüggemann, Brüggemann (1879).

Genus *Lobophyllia* de Blainville, 1830.

Lobophyllia corymbosa (Forskäl) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (sheltered reef, 0 - 20 m), passe, reef pool.
Recorded from Mauritius : Milne-Edwards and Haime (1849), as *L. rudis* Milne-Edwards and Haime, Ortmann (1888), Matthai (1928), Crossland (1952).
from Mauritius and Mascarene islands : Yabe and *al.* (1936).
from Rodriguez : Brüggemann (1879), as *L. umbellata* Brüggemann, Matthai (1928), Crossland (1952).

Lobophyllia costata (Dana) : Mauritius :
rare : Outer slope (5 - 20 m).

Lobophyllia hemprichii (Ehrenberg) : Reunion, Mauritius, Rodriguez :
common : Outer slope (10 - 40 m), passe (0 - 10 m).
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Genus *Symphyllia* Milne-Edwards and Haime, 1848.

Symphyllia recta (Dana) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves, volcanic flagstone, 15 - 40 m), passe (0 - 15 m).

Genus *Parascolymia* Wells

Parascolymia vitiensis (Brüggemann) : Reunion, Mauritius :
common : Outer slope (volcanic flagstone, 20 - 40 m).

Family PECTINIIDAE Vaughan and Wells, 1943.

Genus *Echinophyllia* Klunzinger, 1879.

Echinophyllia aspera (Ellis and Solander) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, volcanic flagstone, 10 - 40 m).

Genus *Oxypora* Saville Kent, 1871.

Oxypora lacera (Verrill) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (spurs and grooves zone, volcanic flagstone, 10 - 40 m), passe (5 - 15 m).

Genus *Mycedium* Oken, 1815.

Mycedium tenuicostatum (Verrill) : Rodriguez :
rare : Outer slope (sheltered reef, 15 - 20 m).

Recorded from Mauritius : Stoddart (1970), Michel (1974).

Mycedium elephantotum (Pallas) : Mauritius :
rare : Passe and reef pool, 5 - 15 m.

Genus *Pectinia* Oken, 1815.

Pectinia cf. lactuca (Pallas) : Reunion :
rare : Outer slope (volcanic flagstone, -35 m).

Suborder CARYOPHYLLIINA Vaughan and Wells, 1943.
Superfamily CARYOPHYLLIICAE Gray, 1847.
Family CAROPHYLLIIDAE Gray, 1847.

Genus *Euphyllia* Dana, 1846.

Euphyllia glabrescens (Chamisso and Eysen Hardt) : Mauritius :
rare : Passe, reef pool, 2 - 15 m.

Genus *Plerogyra* Milne-Edwards and Haime, 1848.

Plerogyra sinuosa Dana : Mauritius :
rare : Reef pool, passe, 2 - 15 m.

Genus *Gyrosmilia* Milne-Edwards and Haime, 1851.

Gyrosmilia interrupta (Ehrenberg) : Reunion, Mauritius :
uncommon : Outer slope (sheltered reef, 5 - 40 m), passe, reef pool, creek

Suborder DENDROPHYLLIINA Vaughan and Wells, 1943.
Family DENDROPHYLLIIDAE Gray, 1847.

Genus *Dendrophyllia* de Blainville, 1830.

Dendrophyllia nigrescens Dana : Mauritius :
rare : Passe, 15 - 20 m.
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Dendrophyllia sp. 1 : Reunion :
rare : Outer slope (sheltered reef) - 15 m.

Dendrophyllia sp. 2 : Mauritius :
rare : Passe, - 20 m.

Other species recorded from Mauritius : *D. ehrenbergiana* Milne-Edwards and Haime, Ortmann (1889); *D. manni* (Verrill), Stoddart (1970), Michel (1974), *D. profunda* (Pourtales), Stoddart (1970), Michel (1974).

from Rodriguez : *D. ehrenbergiana* Milne-Edwards and Haime, Brüggemann (1879).

Genus *Tubastrea* Lesson, 1834.

Tubastrea aurea (Quoy and Gaimard) : Mauritius, Rodriguez :
sporadic : Reef front, outer slope (0 - 5 m).
Recorded from Mauritius as *D. coccinea* (Michelin) by : Michelin (1845), Stoddart (1970), Michel (1974).

Tubastrea micrantha (Ehrenberg) : Mauritius, Rodriguez :
uncommon : Passe (10 - 20 m).
Recorded from Mauritius : Ortmann (1888), Stoddart (1970), Michel (1974).

Genus *Turbinaria* Oken, 1815.

Turbinaria mesenterina (Lamarck) : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (sheltered reef, 0 - 5 m), reef front, outer reef flat.
Recorded from Mauritius : Ortmann (1888).
from Rodriguez : Brüggemann (1879), Wells (1954), Bernard (1896), Vaughan (1918).

Turbinaria crater (Pallas) : Mauritius :
rare : Outer slope (volcanic flagstone, 40 m).

Turbinaria peltata Esper : Reunion, Mauritius :
common : Outer slope (volcanic flagstone, 20 - 50 m).
Recorded from Mauritius : Bernard (1896), Vaughan (1918).

Turbinaria cf. irregularis : Reunion, Mauritius, Rodriguez :
sporadic : Outer slope (volcanic flagstone, 20 - 35 m).
Recorded from Mauritius : Wells (1954), Bernard (1896).

Turbinaria cf. porcellanea Bernard : Rodriguez :
rare : Outer slope (sheltered reef, - 20 m), passe, - 20 m.

Turbinaria sp. : Mauritius :
rare : Outer slope (spurs and grooves zone, - 20 m).

Genus *Heteropsammia* Milne-Edwards and Haime, 1848.

Heteropsammia michelini Milne-Edwards and Haime.
Recorded from Mauritius : Stoddart (1970), Michel (1974).

Subclass OCTOCORALLIA Haeckel
Order COENOTHECALIA Bourne, 1895.
Family HELIOPORIDAE Moseley, 1876.

Genus *Heliopora* Moseley, 1876.

Heliopora coerulea (Pallas) : Mauritius, Rodriguez :
uncommon : Outer slope (8 - 12 m), outer reef flat, lagoon coral formations.
Recorded from Mauritius : Michelin (1845), Michel (1974).
from Rodriguez : Tixier-Durivault (1972).

Class HYDROZOA Owen
Order MILLEPORINA Hickson
Family MILLEPORIDAE Flemming

Genus *Millepora* Linnaeus

Millepora platyphylla Ehrenberg and Hemprich : Reunion, Mauritius, Rodriguez :
common : Outer slope (spurs and grooves zone, 0 - 15 m), reef front, outer reef flat.
Recorded from Mauritius : Ortmann (1892), as *M. verrucosa* Milne-Edwards and Haime, Boschma (1957), Michel (1974).

from Rodriguez : Brüggemann (1879), as *M. verrucosa* Milne-Edwards and Haime.

Millepora exaesa Forskäl : Rodriguez :
rare : Inner reef flat
Recorded from Rodriguez : Brüggemann (1879), as *M. gonagra* Milne-Edwards and Haime.

Millepora intricata Milne-Edwards and Haime : Mauritius, Rodriguez :
sporadic : Inner slope, reef pool, 2 - 8 m.

Millepora tenera Boschma : Mauritius, Rodriguez :
sporadic : Inner slope, reef pool, lagoon coral formations, 2 - 5m.
Recorded from Mauritius : Boschma (1957), Michel (1974).
Other species recorded from Mauritius : *M. dichotoma* Forskäl, Michel (1974); *M. truncata* Dana, Michel (1974); *M. tuberosa* Boschma, Boschma (1966), Michel (1974).

Order STYLASTERINA Hickson and England
Family STYLASTERIDAE Gray
Subfamily DISTICHOPORINAE Stechow

Genus *Distichopora* Lamarck

Distichopora violacea (Pallas) : Reunion ?, Mauritius, Rodriguez :
uncommon : Outer slope (spurs and grooves zone, reef tunnel overhanging sidewall, 2 - 10 m).
Recorded from Mauritius : Michelin (1845), Michel (1974).

Conclusions

The list given here cannot be exhaustive for various reasons: first some of the specimens collected are now being identified and do not appear here. Second some genera and species still await discovery in this part of the Indian Ocean. Thus only in the most recent studies of the outer slope of the reefs of the archipelago has the presence of the following genera been detected : *Stylocoeniella, Culicia, Caulastrea, Gyrosmilia, Pectinia, Pseudocolumnastrea.*

In order not to increase the risk of errors we have mentioned separately the species appearing in the lists of Stoddard (1970) and Michel (1974), with the exception of those species actually seen during the present survey. In fact in Michel's list only 50 species, belonging to 22 genera, exist in the collections of the Mauritius Institute, Port-Louis (Mauritius) where they are represented by one or only a few specimens of which the names originally provided by P. Boshoff. Further 48 other species (27 of which occur in the genera *Acropora* and *Porites*) are listed or described in old papers and are in need of revision.

Though it might be premature to draw final conclusions from the present survey (see table) some findings are evident:

The greater range of genera seen in Mauritius is due to a greater variety of biotopes in the reef than exists in Réunion.

The relatively high number of genera and species found in Réunion however is due to a better knowledge of the outer slope of the reefs of that island.

The relatively low figures given for Rodriguez are due on the one hand to the fact that through lack of facilities studies have been less intensive than on the other two islands; on the other hand the presence of an important "soil pollution" which extends from the lagoons to the outer slope constitutes an obstacle to the development of the coral population both qualitatively and quantitatively. The cause of the "pollution" is the extensive clearing of forests on the island which moreover lies right in the path of the main tropical cyclones.

With the exception of Mauritius the lack of data concerning the abundance of genera and species has long led to the belief that the Mascarene archipelago was relatively poor in scleratinian corals. The present check list, however, shows a wealth comparable to that of the neighbouring islands of the S.W. Indian Ocean. Rosen (1971) gives (including inferred and doubtful genera records) the following figures : Maldives, South (60); Seychelles (57); Aldabra (55); Chagos (56); Cargados (47); Farquhar (52); Comoros (48); Amirantes (54). Further the results obtained to date in the Mascarenes confirm the generic diversity model for reefs in the Indian Ocean of the same author.

The specimens on which the present provisional list have been based are currently being compared with material previously collected in the same part of the Indian Ocean and located in the main European museums.

Acknowledgements

Thanks are due to my friend and diving partner Dr. L. Montaggioni (Dept of Geology, Centre Universitaire, La Réunion). I should like to thank Dr. M. Pichon (James Cook University, Townsville, Australia) for identifying some scleractinian corals in the present list. I am grateful to C. Michel, Director, Mauritius Institute; D. Ardill of the Mauritius Fisheries Office; and J. Forget, formerly Magistrate of Rodriguez for their assistance in many ways while I was in Mauritius and Rodriguez.

References

General studies on the Coral reefs from Mascarene Archipelago.

Baissac, J. de B, Lubet, P. and Michel, C. (1962). Les biocoenoses benthiques littorales de l'Ile Maurice. *Rec. Trav. Stn. Mar. Endoume* 25, 39 : 253-291.

Faure, G. (1973). Morphology and bionomy of the Coral reef discontinuities in Rodriguez island (Mascarene Archipelago, Indian Ocean). *Proc. 2nd Internat. Symp. Coral reefs, Brisbane* (in press).

Faure, G. (1974). Etude comparative des récifs coralliens de l'Archipel des Mascareignes (Océan Indien). *Colloque Commerson St-Denis (Réunion), Oct. 1973, Bull. Mauritius inst.* (in press).

Faure, G. and Montaggioni, L. (1970). Le récif corallien de St-Pierre de La Réunion (Océan Indien): Géomorphologie et répartition des peuplements. *Rec. Trav. Stat. Mar. Endoume, Hors sér., suppl.* 10 : 271-284.

Faure, G. and Montaggioni, L. (1971a). Les récifs coralliens de l'Ile Rodrigue (Archipel des Mascareignes, Océan Indien) : Géomorphologie et répartition des peuplements. *Proc. symp. Indian Ocean and adjacent seas, Jan. 1971, Cochin* (in press).

Faure, G. and Montaggioni, L. (1971 b). Les récifs coralliens sous le vent de l'Ile Maurice (Archipel des Mascareignes, Océan Indien) : Morphologie et bionomie de la pente externe. *C.R. Acad. Sci. Paris,* 273 : 1914-1916.

Faure, G. and Montaggioni, L. (1974) : Les récifs coralliens au vent de l'Ile Maurice (Archipel des Mascareignes, Océan Indien) : Morphologie et bionomie de la pente externe. *C.R. Acad. Sci. Paris* (in press).

Gardiner, J.S. (1936). The reefs of the western Indian Ocean. II, The Mascarene region. *Trans Linn. Soc. London,* 2nd ser., 19 : 426-436.

Montaggioni, L. (1970). Répartition et zonation géomorphologique des structures récifales de l'Ile de la Réunion (Océan Indien). *C.R. Acad. Sci. Paris,* 270 : 663-665.

Montaggioni, L. (1973). Coral reefs and Quaternary shore-lines in the Mascarene Archipelago. *Proc. 2nd Internat. Symp. Coral reefs, Brisbane* (in press).

Pichon, M. (1967). Caractéres généraux des peuplements benthiques des récifs et lagons de l'Ile Maurice. *Cahiers O.R.S.T.O.M., Océanographie,* V, 4 : 31-45.

Pichon, M. (1971). Comparative study of the main features of some coral reefs of Madagascar, La Reunion and Mauritius. In D.R. Stoddart and C. M. Yonge *: Regional variation in Indian Ocean coral reefs. Symp. Zool. Soc. London,* 28 : 185-216.

Rosen, B.R. (1971). The distribution of reef coral genera in the Indian Ocean. *Symp. Zool. Soc. London,* 28 : 263-299.

Bibliography of works recording reef corals from Mascarene Archipelago.

Bernard, H.M. (1896). *Catalogue of the madreporarian corals in the British Museum (Natural History)*, 2 : The genus *Turbinaria,* the genus *Astreopora* London : British Museum (Natural History).

Bernard, H.M. (1897). *Catalogue of the madreporarian corals in the British Museum (Natural History)*, 3 : The genus *Montipora,* The genus *Anacropora.* London : British Museum (Natural History).

Bernard, H.M. (1903). *Catalogue of the madreporarian corals in the British Museum (Natural History)*, 4 : The family PORITIDAE. I. The genus *Goniopora.* London : British Museum (Natural History).

Bernard, H.M. (1905). *Catalogue of the madreporarian corals in the British Museum (Natural History)*, 5 : The family PORITIDAE. II. The genus *Porites. I. Porites* of the Indopacific region. London : British Museum (Natural History).

Boschma, H. (1948). The species problem in *Millepora. Zool. Verhand. Leiden.* 1 : 3-115.

Boschma, H. (1966). On a new species of *Millepora* from Mauritius with notes on the specific characters of *Millepora exaesa. Proc. K. ned. Akad. Wet.* (C), 69 : 409-419.

Brook, G. (1891). Description of new species of *Madrepora* in the collection of British Museum. *Ann. Mag. Nat. Hist.* (6) 8 : 458-471.

Brook, G. (1892). Preliminary descriptions of 40 new species of *Madrepora* in the collection of British Museum. Part II. *Ann. Mag. Nat. Hist.* (6), 10 : 451-465.

Brook, G. (1893). *Catalogue of the madreporarian corals in the British Museum (Natural History)*, 1 : The genus *Madrepora.* London : British Musuem Natural History.

Brüggemann, F. (1878). Neue Korallen-Arten aus dem Rothen Meer und von Mauritius. *Abh. naturw. Ver. Bremen* 5 : 395-400.

Brüggemann, F. (1879). Corals (in the collections from Rodriguez : Zoology) *Phil. Trans. R. Soc.* 168 : 569-579.

Chevalier, J.P. (1971). Les Scleractiniares de la Mélanaisie française. *Fond. Singer Polignac* 5 : 9-307.

Crossland, C. (1948). Reef corals of the South African coast. *Ann. Natal. Mus.* 11 : 169-205.

Crossland, C. (1952). Madreporaria, Hydrocorallinae, *Heliopora* and *Tubipora*. *Scient. Rep. Gt Barrier reef exped.* 6 : 85-257.

Dana, J.D. (1846-1849). *Zoophytes. United States Exploring Expedition during the years* 1838-1842 *Under the Command of Charles Wilkes, U.S.N.* 7 (6) : 1-740, atlas.

Freycinet, L. (1828). Tableau de la distribution géographique des polypiers recueillis pendant le voyage autour du monde de M. Le Capitaine Louis de Freycinet. *Ann. Sci. Nat.* 14 : 250-252.

Gravier, C. (1911). Les recifs de coraux et les madréporaires de la baie de Tadjourah (Golfe d'Aden). *Ann. Inst. Oceanogr., Monaco* 2 (3) : 1-104.

Hoffmeister, J.E. (1925). Some corals from American Samoa and the Fiji islands *Carnegie Institution of Washington* 22 : 1-82.

Klunzinger, C.B. (1879). *Die Korallenthiere des rothen Meeres.* Berlin : Gutmann *(Zweiter Theil, Dritter Thiel : Die Steinkorallen).*

Lamarck, J.B. (1816). *Histoire naturelle des animaux sans vertèbres* 2.

Ma, T. Y. H. (1959). Effect of water temperatures on growth of reef corals. *Oceanographia Sin.* (Spec. vol.) 1 : 1-116.

Matthai, G. (1924). Report on the madreporarian corals in the Indian Museum, Calcutta (1). *Mem. Indian Mus.* 8 : 1-59.

Matthai, G. (1928). *Catalogue of the madreporarian corals in the British Museum (Natural History)* 7. *A monograph of the recent meandroid ASTRAEIDAE.* London : British Museum (Natural History) : 228 p.

Michel, C. (1974). Notes on marine biology studies made in Mauritius : *Bull. Mauritius Inst.* 7, 2 : 1-284.

Michelin, M. (1845). Zoophytes, Echinodermes et Stellérides. Essai d'une faune de l'Ile Maurice, publiée avec les matériaux et la note laissés par Julien Desjardins, sous la direction de M.F.E. Guérin Mineville. *Mag. Zool.* (2) : 3-6.

Milne-Edwards, H. and Haime, J. (1857-1860). *Histoire naturelle des coralliaires ou polypes proprement dits.* 3 volumes, Atlas, librairie encyclopédique Rovet, Paris.

Möbius, K., Richters, F. and Martens, E. Von (1880). *Beiträge zur Meeresfauna der insel Mauritius und der Seychelles.* Berlin : Gutmann.

Ortmann, A. (1888). Studien über systematik und geographische Verbreitung der Steinkorallen. *Zool. Jb. (Syst.)* 3 : 143-188.

Ortmann, A. (1889). Beobachtungen an Steinkorallen von der Südküste Ceylons. *Zool. Jb. (Syst.)* 4 : 493-590.

Ortmann, A. (1892). Die Korallriffe von Dar-es-Salaam und umgegund. *Zool. Jb. (Zool.)* 6 : 631-670.

Pichon, M. (1971). *Horastrea indica* n. gen., n. sp., a new hermatypic Scleractinian coral from the South West Indian Ocean (Cnidaria, Anthozoa, Madreporaria). *Rev. Zool. Bot. Afr.,* LXXXIII, 1-2 : 165-172.

Stock, J. H. (1966). Cyclopoida Siphonostoma from Mauritius (Crustacea copepoda). *Beaufortia* 13 (159) : 145-194.

Stoddart, D.R. (1970). Report on a visit to Mauritius. 12-21 July 1969. *Royal Society Aldabra research committee,* : 1-22.

Thiel, M.F. (1932). Resultats scientifiques du voyage aux Indes orientales néerlandaises de LL. AA.RR. le Prince et la Princesse Léopold de Belgique. Madreporaria. *Mem. Mus. Roy. Hist. Nat. Belgique.,* hors série, Vol.II, fasc. 12 : 3-169.

Tixier-Durivault, A. (1972). Nouvel apport d'Octocoralliaires de Madagascar et des îles avoisinantes. *Tethys. Suppl.,* 3 : 11-68.

Vaughan, T.W. (1918). Some shoal-water corals from Murray island (Australia) Cocos-Keeling islands and fanning island. *Pap. Dep. mar. Biol. Carnegie Instn. Wash.* 9 : 51-234.

Wells, J.W. (1954). Bikini and Nearby atolls : 2. Oceanography (Biologic). Recent corals of the Marshall Islands. *Prof. Pap. U.S. Geol. Surv.* 260 (I) : 385-486.

Wijsman-Best, M. (1972). Systematics and ecology of New Caledonian Faviinae (Coelenterata - Scleractinia). *Bijdr. Dier Kunde,* 42 (1) : 3-90.

Yabe, H., Sugiyama, T. and Eguchi, M. (1936). Recent reef building corals from Japan and the South Sea Islands under the japanese Mardate. *Science Reports Tohoku Imp. University, Sendaï, Japan,* 2nd ser. (Geology), special vol. I : 66 p.

Yabe, H. and Sugiyama, T. (1941). Recent reef building corals from Japan and the South Sea Islands under the Japanese Mandate II, *Science Reports Tohoku Imp. University, Sendaï, Japan,* 3rd ser. (Geology). Special vol. II.: 67-91.

Table 1. Distribution of Scleractinian Corals

Localities	Scleractinian corals		Non-Scleractinian corals		Total	
	Genera	Species	Genera	Species	Genera	Species
Reunion	49	105	2	2	51	107
Mauritius	52	116	3	5	55	121
Rodriguez	38	84	3	6	41	90
Total	55	129	3	6	58	135

ATOLL RESEARCH BULLETIN

NO. 204.

ANNOTATED CHECK LIST OF OCTOCORALLIA IN THE MASCARENE ARCHIPELAGO, INDIAN OCEAN

by Gérard Faure

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

ANNOTATED CHECK LIST OF OCTOCORALLIA IN THE MASCARENE ARCHIPELAGO, INDIAN OCEAN

by

Gérard Faure[1]

Summary

A total of 112 species belonging to 37 genera of the Mascarene Octocorallia known to date are listed in this paper. Some of them were collected by the author, by means of scuba, and determined by Tixier-Durivault (Museum National d'Histoire Naturelle, Paris). The others were recorded in former papers, specially by Tixier-Durivault (1966, 1972) and Michel (1974).

Introduction

The Mascarene Archipelago is situated in the western Indian Ocean about 700 km, to the east of Madagascar, in the longitudes 55°32' - 63°20' and latitudes 21°7' - 19°40'. It is composed of three volcanic islands : Réunion, Mauritius, Rodriguez, forming separate geological topographical units. The total surface of areas of the coral reefs are very different according to the islands : negligible (12 km^2), compared with that of the island (2500 km^2) in Reunion, more important in Mauritius (300 km^2 for 1800 km^2) and very important in Rodriguez where the reef is overlapping 200 km^2 as compared to 110 km^2 in terrestrial surface.

General Mascarene reef studies were done by : Gardiner (1936), Baissac and *al.* (1962), Pichon (1967, 1971), Faure and Montaggioni (1970, 1971a, 1971b, 1974), Faure (1973, 1974), Montaggioni (1970, 1973). There are some records of Octocorallia from the Mascarene Archipelago in the works of : Ellis and Solander (1786), Lamarck (1816), Templeton (1835), Michelin (1845), Milne-Edwards and Haime (1857), Studer (1878), Brüggemann (1879), Ridley (1882a, 1882b, 1882c), Thomson and MacKinnon (1910), Simpson (1910), Stiasny (1940), but there are very few works concerning the systematics of Octocorallia from the Archipelago, except those of Tixier-Durivault (1966, 1972), Michel (1974).

---

[1]Station Marine d'Endoume, Marseille; Centre Universitaire, St. Clothilde, Réunion.
(Manuscript received June 1975-- Eds.)

This paper intends to serve as a first provisional list of the Octocorallia in the Mascarene islands.

Order ALCYONACEA Lamouroux, 1816

Family ALCYONIIDAE Lamouroux, 1812

Genus *Alcyonium* Linné, 1758

Alcyonium aspiculatum Tixier-Durivault, 1965
RO 65 A[1] : Passe of Port Sud-Est, - 8m : Rodriguez
RO 17 : Branched coral reef flat *(Acropora pharaonis)*, Port Mathurin : Rodriguez
RO 22 : Reef flat with scattered coral growth, (Inner reef flat), Pointe au Sable : Rodriguez
MAU 34 : Lagoon of Trou aux Biches, - 2m : Mauritius
Alcyonium legitimum Tixier-Durivault, 1970
RO 51 : Outer slope, reef of Anse aux Anglais, - 20m : Rodriguez
RO 52 : Passe Grenade, - 18m : Rodriguez

Genus *Cladiella* Gray, 1869

Cladiella australis (MacFadyen, 1936)
MAU 67 : Reef front, La Preneuse : Mauritius
Cladiella ceylonica (Pratt, 1905)
MAU 29 : Reef front, Trou aux Biches : Mauritius
Cladiella hicksoni (Tixier-Durivault, 1944)
MAU 3 A : Outer reef flat, Pointe d'Esny : Mauritius
Cladiella krempfi (Hickson, 1919)
RO 10 : Reef front, Pointe aux Cornes : Rodriguez
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Cladiella laciniosa (Tixier-Durivault, 1944)
MAU 3 B : Outer reef flat, Pointe d'Esny : Mauritius
Cladiella latissima (Tixier-Durivault, 1944)
MAU 26 : Outer reef flat, Trou aux Biches : Mauritius
Cladiella pachyclados (Klunzinger, 1877)
RO 80 B : Outer slope reef of Quatre Vingts Brisants, - 20 m : Rodriguez
Cladiella ramosa Tixier-Durivault, 1970
MAU 46 : Bay of Arsenal, - 5 m : Mauritius
RO 7 : Reef front Anse Tamarins : Rodriguez
Cladiella sphaerophora (Ehrenberg, 1834)
Rodriguez : in Brüggemann (1879)

Genus *Lobophytum* Marenzeller, 1886

Lobophytum altum Tixier-Durivault, 1956
RO 5 : Compact reef flat (inner reef flat) Anse aux Anglais : Rodriguez
Lobophytum batarum Moser, 1919
MAU 41 : Outer slope, Trou aux Biches, - 20 m : Mauritius

---

[1] Author's collection.

Lobophytum compactum Tixier-Durivault, 1956
MAU 68 : Outer slope, reef of Flic en Flac, - 15 m : Mauritius
Lobophytum crassum Marenzeller, 1886
REU 172 : Outer slope, reef of cap Lahoussaye - 15 m : Réunion
Mauritius : in Tixier-Durivault (1956), Michel (1974)
Lobophytum crebriplicatum Marenzeller, 1886
RO 14 A : Outer slope, reef of Port-Mathurin, - 10 m : Rodriguez
RO 50 B : Outer slope, reef of Anse aux Anglais, - 10 m : Rodriguez
REU 173 : Outer slope, reef of cap Lahoussaye, - 15 m : Réunion
REU 189 B : Outer slope, reef Trois Bassins, - 30 m : Réunion
Lobophytum hedleyi Whitelegge, 1897
RO 39 : Reef flat with microatolls, Port Sud-Est : Rodriguez
Lobophytum lamarcki Tixier-Durivault, 1956
MAU 1 : Outer reef flat, Pointe d'Esny : Mauritius
Lobophytum mirabile Tixier-Durivault, 1956
REU 171 A : Outer slope, reef cap Lahoussaye, - 15 m : Réunion
Lobophytum patulum Tixier-Durivault, 1956
RO 66 B : Passe of Port Sud-Est, - 20 m : Rodriguez
Lobophytum pauciflorum (Ehrenberg, 1834)
MAU 42 : Outer slope, Troux aux Biches, - 20 m : Mauritius
REU 180 : Volcanic flagstone (outer slope), reef of l'Hermitage, - 35 m : Réunion
Lobophytum robustum Tixier-Durivault, 1957
MAU 12 : Backreef channel, Ile aux Aigrettes, - 5 m : Mauritius
Lobophytum sarcophytoïdes Moser, 1919
REU 151 : Reef front of St-Pierre : Réunion
REU 169 : Outer slope, cap Lahoussaye, - 15 m : Réunion
Lobophytum schoedei Moser, 1919
MAU 58 : Outer slope, reef of Pointe aux Sables, - 10 m : Mauritius
Lobophytum variatum Tixier-Durivault, 1957
REU 155)
REU 156) : Reef front of St-Pierre : Réunion

Genus *Parerythropodium* Kükenthal, 1916

Parerythropodium fulvum (Forskal, 1775)
RO 59 A : Outer slope, reef of Grande Pointe, - 15 m : Rodriguez

Genus *Sarcophyton* Lesson, 1834

Sarcophyton crassocaule Tixier-Durivault, 1946
RO 16 B : Outer slope, reef of Port-Mathurin, - 15 m : Rodriguez
RO 40 B : Outer reef flat, Port Sud-Est : Rodriguez
RO 48 A : Outer slope, Middle ground reef, - 8 m : Rodriguez
Sarcophyton glaucum (Quoy et Gaimard, 1833)
REU 189 A : Outer slope, reef of Trois Bassins, - 30 m : Réunion
RO 40 A : Reef flat with microatolls, Port Sud-Est : Rodriguez
RO 46 : Outer slope, Port-Mathurin, - 15 m : Rodriguez
RO 58 : Outer slope, reef of Grande Pointe, - 15 m : Rodriguez
Sarcophyton latum (Dana 1846)
Rodriguez : in Brüggemann (1879)
Sarcophyton molle Tixier-Durivault, 1946
REU 160 : Volcanic flagstone (outer slope), reef of l'Hermitage, - 25 m : Réunion

REU 161 : Volcanic flagstone (outer slope), reef of l'Hermitage, - 30 m : Réunion
REU 184 : Volcanic flagstone (outer slope), reef of La Saline, - 35 m : Réunion
Sarcophyton regulare Tixier-Durivault, 1958
REU 170 : Outer slope, reef of cap Lahoussaye, - 15 m : Réunion
RO 57 : Outer slope, reef of Grande Pointe, - 15 m : Rodriguez
Sarcophyton solidum Tixier-Durivault, 1958
REU 182 B : Volcanic flagstone (outer slope), reef of l'Hermitage, - 35 m : Réunion
Sarcophyton spongiosum Thomson and Dean, 1931
REU 153 : Lagoon of St-Pierre : Réunion
Sarcophyton stolidum Verseveldt, 1971
MAU 40 : Outer slope, Trou aux Biches, - 20 m : Mauritius
Sarcophyton trocheliphorum Marenzeller, 1886
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Genus *Sinularia* May 1898

Sinularia arborea Verseveldt, 1971
MAU 40 : Outer slope, reef of Trou aux Biches, - 25 m : Mauritius
Sinularia crassa Tixier-Durivault, 1945
MAU 2 : Outer reef flat, Pointe d'Esny : Mauritius
Sinularia densa (Whitelegge, 1897)
MAU 66 : Reef front, La Preneuse : Mauritius
REU 179 : Outer slope, reef of St-Gilles, - 25 m : Réunion
RO 14 B : Outer slope, reef of Port-Mathurin, - 10 m : Rodriguez
Sinularia dura (Pratt, 1903)
MAU 17 C : Outer slope, Ile de La Passe, - 10 m : Mauritius
Sinularia erecta Tixier-Durivault, 1945
MAU 17 A : Outer slope, Ile de La Passe, - 10 m : Mauritius
Sinularia grayi Tixier-Durivault, 1945
REU 159 : Outer slope, reef of l'Hermitage, - 20 m : Réunion
RO 56 : Outer slope, reef of Grand Baie, - 18 m : Rodriguez
Sinularia leptoclados (Ehrenberg, 1834)
RO 65 B : Passe of Port Sud-Est, - 8 m : Rodriguez
Sinularia macropodia (Hickson and Hiles, 1900)
REU 181 : Volcanic flagstone (outer slope), reef of l'Hermitage, - 35 m : Réunion
RO 49 : Outer slope, reef of Middle Ground, - 10 m : Rodriguez
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Sinularia marenzelleri (Wright and Studer, 1889)
MAU 16 : Channel of Mahebourg, - 20 m : Mauritius
RO 48 B : Outer slope, reef of Middle Ground, - 10 m : Rodriguez
Sinularia pedunculata Tixier-Durivault, 1945
MAU 37 : Outer slope, reef of Trou aux Biches, - 20 m : Mauritius
RO 16 A : Outer slope, reef of Port-Mathurin, - 10 m : Rodriguez
Sinularia polydactyla Tixier-Durivault, 1945
MAU 22 A : Outer slope, Horseshoe reef, - 8 m : Mauritius
MAU 45 : Bay of Arsenal, - 3 m : Mauritius
MAU 49 : Outer slope, reef of Trou aux Biches, - 28 m : Mauritius
MAU 54 : Reef front, Pointe au Sable : Mauritius
REU 150 : Reef front of St-Pierre : Réunion
REU 178 : Outer slope, reef of St-Gilles, - 22m : Réunion

REU 154 : Lagoon of St-Pierre : Réunion
RO 60 B : Passe of Grand-Bassin, - 12 m : Rodriguez
Sinularia querciformis (Pratt, 1903)
RO 66 A : Passe of Port Sud-Est, - 8 m : Rodriguez
Sinularia rigida var. *amboinensis* (Burchardt, 1902)
Réunion : in Tixier-Durivault (1972)
Sinularia robusta MacFadyen, 1936
MAU 30 : Reef front, reef of Trou aux Biches : Mauritius
Sinularia simpsoni Tixier-Durivault, 1945
REU 152 : Lagoon, reef of St-Pierre : Réunion
RO 50 A : Outer slope, reef of Anse aux Anglais, - 6 m : Rodriguez
RO 53 B : Outer slope, reef of Port-Mathurin, - 12 m : Rodriguez
Sinularia triaena Kolonko, 1926
MAU 39 : Outer slope, reef of Trou aux Biches, - 20 m : Mauritius
Réunion : in Tixier-Durivault (1972)
Sinularia venusta Tixier-Durivault, 1970
REU 158 : Outer slope, reef of Boucan Canot, - 15 m : Réunion
Sinularia whiteleggei Lüttschwagger, 1914
RO 13 : Reef front, reef of Pointe aux Cornes : Rodriguez
RO 53 A : Outer slope, reef of Port-Mathurin, - 12 m : Rodriguez
MAU 4 : Outer reef flat, reef of Pointe d'Esny : Mauritius
MAU 5 : Outer reef flat, reef of Pointe d'Esny : Mauritius
MAU 10 : Backreef channel of Ile aux Aigrettes, - 5 m : Mauritius
MAU 17 B : Reef front, outer slope, reef of Ile de la Passe, 0 - 6 m : Mauritius

Family NEPTHEIDAE Gray, 1862

Genus *Nephthea* Savigny, 1817

Nephthea cupressiformis Kükenthal, 1904
RO 71 : Passe of Port Sud-Est, - 20 m : Rodriguez

Genus *Roxasia* Tixier-Durivault and Prevorsek, 1957

Roxasia gravieri (Kükenthal, 1910)
Mauritius : in Tixier-Durivault (1972), Michel (1974), Tixier-Durivault and d'Hondt 1973 (1974)
Roxasia hirsuta Tixier-Durivault and Prevorsek, 1960
REU 188 : Volcanic flagstone (outer slope), reef of Pointe des Aigrettes, - 40 m : Réunion
Roxasia mirabilis (Henderson, 1909)
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Genus *Stereonephthya* Kükenthal, 1905

Stereonephthya unicolor (Gray, 1862)
REU 157 : Outer slope, reef of Boucan-Canot, - 15 m : Réunion
Stereonephthya sp.
RO 80 A : Outer slope, reef of Quatre-Vingts Brisants, - 20 m : Rodriguez

Genus *Dendronephthya*

Dendronephthya divaricata (Gray)
Mauritius : in Thomson and MacKinnon (1910), Michel (1974)

Family XENIIDAE Ehrenberg, 1828

Genus *Anthelia* Lamarck, 1816

Anthelia desjardiana Templeton, 1841
Mauritius : in Milne-Edwards and Haime (1857), Michel (1974)
Anthelia flava (May, 1899)
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Genus *Cespitularia* Milne-Edwards and Haime, 1850

Cespitularia densa Tixier-Durivault, 1966
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Cespitularia mantoni Hickson, 1931
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Genus *Sympodium* Ehrenberg, 1834

Sympodium coeruleum Ehrenberg, 1834
MAU 6 : Outer reef flat, reef of Pointe d'Esny : Mauritius

Genus *Xenia* Lamarck, 1816

Xenia blumi Schenk, 1896
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Xenia distorta Tixier-Durivault, 1966
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Xenia elongata Dana, 1846
REU 149 : Reef front, reef of St-Pierre : Réunion
Xenia florida (Lesson, 1826)
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Xenia garciae Bourne, 1894
Mauritius : in Michel (1974)
Xenia plicata Schenk, 1896
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Xenia ternatana Schenk, 1896
Mauritius : in Tixier-Durivault (1972)

Order COENOTHECALIA Bourne, 1895
Family HELIOPORIDAE Moseley, 1876

Genus *Heliopora* Blainville, 1830

Heliopora coerulea (Pallas, 1766)
RO 110 : Outer reef flat, reef of Grande Pointe : Rodriguez
RO 302 : Outer slope, reef of Quatre-Vingts Brisants, - 12 m : Rodriguez
MAU 155 : Outer slope, reef of Ile Plate, - 8 m : Mauritius
MAU 404 : Lagoon, reef Pointe Bambou : Mauritius

Order GORGONACEA Lamouroux, 1816
Suborder SCLERAXONIA Studer, 1887
Family SUBERGORGIIDAE Gray, 1859

Genus *Subergorgia* Gray, 1857

Subergorgia mollis (Nutting, 1910)
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Subergorgia reticulata (Ellis and Solander, 1786)
Mauritius : in Tixier-Durivault (1972), Michel (1974)
Subergorgia suberosa (Pallas, 1766)
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Family CORALLIIDAE Lamouroux, 1812

Genus *Corallium* Cuvier, 1798
Corallium stylasteroides Ridley, 1882
Mauritius : in Ridley (1882a), Tixier-Durivault (1972), Michel (1974)

Family MELITHAEIDAE Gray, 1870

Genus *Melithaea* Milne-Edwards and Haime, 1857
Melithaea ochracea (Lamarck, 1816)
Mauritius : in Michelin (1845), Michel (1974)

Genus *Wrightella* Gray, 1870
Wrightella coccinea (Ellis and Solander, 1786)
REU 185 A : Volcanic flagstone (outer slope), reef of Pointe aux Aigrettes, - 40 m : Réunion
Mauritius : in Ellis and Solander (1786), Milne-Edwards and Haime (1857)

Family PARASIDIDAE Aurivillius, 1931

Genus *Parisis* Verrill, 1864
Parisis fruticosa Verrill, 1864
Mauritius : in Wright and Studer (1889), Tixier-Durivault (1972), Michel (1974)

Suborder HOLAXONIA Studer, 1887

Family ACANTHOGORGIIDAE Gray, 1859

Genus *Acanthogorgia* Verrill, 1868
Acanthogorgia spinosa Hiles
Mauritius : in Thomson and Russel (1909), Michel (1974)

Genus *Anthogorgia* Verrill, 1868
Anthogorgia divaricata Verrill, 1868
Mauritius : in Tixier-Durivault (1972), Michel (1974)

Family PARAMURICEIDAE Bayer, 1956

Genus *Muricella* Verrill, 1869
Muricella grandis Nutting, 1910
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)
Muricella perramosa Ridley, 1882
Mauritius : in Ridley (1182c), Tixier-Durivault (1972), Michel (1974)
Muricella rubra Thomson, 1905
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Muricella tenera Ridley, 1884
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Genus *Paracis* Kükenthal, 1919

Paracis orientalis (Ridley, 1882)
Mauritius : in Wright and Studer (1889), Tixier-Durivault (1972), Michel (1974)

Genus *Villogorgia* Duchassaing and Michelotti, 1860

Villogorgia alternans (Wright and Studer, 1889)
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)
Villogorgia ceylonensis (Thomson and Henderson, 1905)
REU 185 B : Volcanic flagstone (outer slope), reef of Pointe aux Aigrettes, - 40 m : Réunion
Villogorgia mauritienis Ridley, 1882
Mauritius : in Ridley (1882b), Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Family PLEXAURIDAE Gray, 1859

Genus *Echinogorgia* Kölliker, 1865

Echinogorgia lami Stiasny, 1940
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)
Echinogorgia pinnata Studer, 1878
Mauritius : in Studer (1878), Tixier-Durivault (1972), Michel (1974)

Genus *Leptogorgia* Milne-Edwards and Haime, 1857

Leptogorgia boryana Milne-Edwards and Haime, 1857
Réunion : in Milne-Edwards and Haime (1957)

Family ELLISELLIDAE Gray, 1859

Genus *Ellisella* Gray, 1868

Elisella candida (Ridley, 1882)
Réunion : in Tixier-Durivault (1972)
Mauritius : in Ridley (1882a), Michel (1974) as *Verrucella candida,* Tixier-Durivault (1972)
Ellisella laevis (Verrill, 1865)
Réunion : in Tixier-Durivault (1972)
Ellisella ramosa Simpson, 1910
Réunion : in Tixier-Durivault (1972)
Ellisella vaughani Stiasny, 1940
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Genus *Junceella* Valenciennes, 1855

Junceella juncea (Pallas, 1766)
REU 185 C : Volcanic flagstone (outer slope), reef of Pointe aux Aigrettes, - 40 m : Réunion
Mauritius : in Simpson (1910), Tixier-Durivault (1972), Michel (1974)
Junceella vinem Valenciennes, 1855
Réunion : in Tixier-Durivault (1972), Milne-Edwards and Haime (1857)
Junceella caliculata Valenciennes, 1855
Réunion : in Milne-Edwards and Haime (1857)

Genus *Nicella* Gray, 1870

Nicella carinata Nutting, 1970
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)
Nicella dichotoma (Gray, 1859)
Mauritius : in Gray (1859), (1870), Simpson (1910), Stiasny (1940), Tixier-Durivault (1972), Michel (1974)
Nicella granifera (Kölliker, 1865)
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Genus *Verrucella* Milne-Edwards and Haime, 1857

Verrucella flexuosa Klunzinger, 1877
Mauritius : in Klunzinger (1877), Thomson and MacKinnon (1910), Michel (1974)
Verrucella verriculata (Milne-Edwards and Haime, 1857)
Mauritius : in Milne-Edwards and Haime (1857), Lamarck (1816), Michel (1974), Tixier-Durivault (1972)

Family ISIDIDAE Lamouroux, 1812

Genus *Isis* Linnaeus, 1766

Isis hippuris (Linnaeus, 1766)
Mauritius : in Michelin (1845), Dana (1846), Milne-Durivault and Haime (1857), Michel (1974)

Genus *Keratoisis* Wright, 1869

Keratoisis grayi Wright, 1869
Mauritius : in Michel (1974)

Family PRIMNOIDAE Gray, 1857
Subfamily PRIMNOINAE Gray, 1857

Genus *Callogorgia* Gray, 1858

Callogorgia flabellum (Ehrenberg, 1834)
Mauritius : in Stiasny (1940), Tixier-Durivault (1972), Michel (1974)

Genus *Pseudoplumarella* Kükenthal, 1915

Pseudoplumarella plumatilis (Milne-Edwards and Haime, 1857)
Mauritius : in Tixier-Durivault (1972)
Réunion : in Milne-Edwards and Haime (1857), Tixier-Durivault (1972)

Subfamily CALYPTROPHORINAE Gray, 1870

Genus *Calyptrophora*

Calyptrophora japonica Gray, 1886
Réunion : in Tixier-Durivault (1972)

Order PENNATULACEA Verrill, 1865
Suborder SUBSELLIFLORAE Kükenthal, 1915
Family VIRGULARIIDAE Verrill, 1868

Genus *Virgularia* Lamarck, 1816

Virgularia densa Tixier-Durivault, 1966
Mauritius : in Tixier-Durivault (1966), (1972), Michel (1974)

Conclusions

From the 112 species listed in this paper, 76 are known from Mauritius, 32 from Réunion, and 27 from Rodriguez. Rather than to a greater diversity of Octocorallia biota, the greater abundance of species in Mauritius must be attributed to a better knowledge from the numerous former records. The lack of affinity of Octocorallia species between the three islands (only 8 species in common for Mauritius and Réunion, 7 Mauritius-Rodriguez, 6 Réunion-Rodriguez, and 2 for the three islands), must be chiefly ascribed to the lack of data in this part of western Indian Ocean. In the meantime it should be observed that more than 70% of scleractinian corals (more than 120 species belonging 55 genera) are common to Mauritius, Rodriguez and Réunion.

If it is too early to compare the Octocorallia distribution with the scleractinian corals, it is a good argument for carrying on ecological and systematical investigations of both in the Archipelago.

References

General studies on the Coral reefs from Mascarene Archipelago

Baissac, J. de B., Lubet, P. and Michel, C. (1962). Les biocoenoses benthiques littorales de l'Ile Maurice. *Rec. Trav. Stn. Mar., Endoume* 25, 39 : 253-291.

Faure, G. (1973). Morphology and bionomy of the coral reef discontinuities in Rodriguez island (Mascarene Archipelago, Indian Ocean). *Proc. 2nd. Internat. Symp. Coral Reefs, Brisbane* (in press).

Faure, G. (1974). Etude comparative des récifs coralliens de l'Archipel des Mascareignes (Océan Indien). *Colloque Commerson, St-Denis (Réunion), Oct. 1973, Bull. Mauritius Inst.* (in press).

Faure, G. and Montaggioni, L. (1970). Le récif corallien de St-Pierre-de-La-Réunion (Océan Indien) : Géomorphologie et répartition des peuplements. *Rec. Trav. Sta. Mar. Endoume,* hors sér., *suppl.* 10 : 271-284.

Faure, G. and Montaggioni, L. (1971a). Les récifs coralliens de l'Ile Rodrigue (Archipel des Mascareignes, Océan Indien) : Géomorphologie et répartition des peuplements. *Proc. Symp. Indian Ocean and adjacent seas, Jan. 1971, Cochin* (in press).

Faure, G. and Montaggioni, L. (1971b). Les récifs coralliens sous le vent de l'Ile Maurice (Archipel des Mascareignes, Océan Indien) : Morphologie et bionomie de la pente externe. *C.R. Acad. Sci. Paris,* 273 : 1914 - 1916.

Faure, G. and Montaggioni, L. (1974). Les récifs coralliens au vent de l'Ile Maurice (Archipel des Mascareignes, Océan Indien) : Morphologie et bionomie de la pente externe. *C.R. Acad. Sci. Paris* (in press).

Gardiner, J.S. (1936). The reefs of the Western Indian Ocean. II, the Mascarene region. *Trans. Linn. Soc. London, 2nd ser.,* 19 : 426-436.

Montaggioni, L. (1970). Répartition et zonation géomorphologique des structures récifales de l'Ile de La Réunion (Océan Indien). *C.R. Acad. Sci. Paris,* 270 : 663-665.

Montaggioni, L. (1973). Coral reefs and Quaternary shore-lines in the Mascarene Archipelago. *Proc. 2nd Internat. Symp. Coral reefs, Brisbane* (in press).

Pichon, M. (1967). Caractéres généraux des peuplements benthiques des récifs et lagons de l'Ile Maurice. *Cahier O.R.S.T.O.M.,* V4 : 31-45.

Pichon, M. (1971). Comparative study of the main features of some coral reefs of Madagascar, La Réunion and Mauritius. In Stoddart and Yonge : regional variation in Indian Ocean Coral reefs. *Symp. Zool. Soc. London,* 28 : 185-216

Stoddart, D.R. (1973). Coral reefs of the Indian Ocean. In Jones and Endean : *Biology and Geology of Coral Reefs,* Vol. I Geology, 1 : 51-92.

Works recording Octocorallia from Mascarene Archipelago

Brüggemann, F. (1879). Corals of Rodriguez. *Phil. Trans. Roy. Soc.* 168 (Extra volume) : 569-579.

Dana, J.D. (1846). Zoophytes. Philadelphia : 740 pp

Ellis, J. and Solander, D. (1786). The Natural history of many curious and uncommon zoophytes collected from various parts of the globe, London : 145-173.

Gray, J.E. (1859). Description of some new genera of litophytes, or stony zoophytes. *Proc. Zool. Soc. Lond.,* 27.

Gray, J.E. (1870). Catalogue of the Litophytes or stony corals in the collection of the British Museum, London.

Klunzinger, C.B. (1877). Die Korallthiere des rothen Meeres I, Die Alcyonarien und Malacodermen, Berlin : 1-98.

Lamarck, J.B. de (1816). Histoire naturelle des animaux sans vertébres t. II.

Michel, C. (1974). Notes on Marine biology studies made in Mauritius. *Bull. Mauritius Inst.* VII, 2 : 1 - 284.

Michelin, M. (1845). Zoophytes, Echinodermes et Stellerides. Essai d'une faune de l'Ile Maurice publiée avec les matériaux et les notes laissés par Julien Desjardins, sous la direction de M.F.E. Guerin. Meneville. *Mag. Zool.*, 2 : 3-6.

Milne-Edwards, H. et Haime, J. (1857). Histoire naturelle des Coralliaires ou Polypes proprement dits. Paris, T.I : 324.

Ridley, S.O. (1882a). On the arrangement of the Coralliidae with description of new or rare species. *Proc. Zool. Soc. Lond.* : 221-233.

Ridley, S.O. (1882b). Contribution to the knowledge of Alcyonaria with descriptions of new species from the Indian ocean and the Bay of Bengal. I, *Ann. Mag. nat. Hist.* (5), 9 : 189-193.

Ridley, S.O. (1882c). Contribution to the knowledge of Alcyonaria with descriptions of new species from the Indian Ocean and the Bay of Bengal, II, *Ann. Mag. nat. Hist.*, (5), 10 : 125-133.

Simpson, J.J. (1910). A revision of the Gorgonellidae, I. The Juncellid group..*Proc. R. Irish Acad.*, 8 (1) : 247-386.

Stiasny, G. (1940). Alcyonaria und Gorgonaria von Mauritius *Arch. neerl. Zool.*, 4 : 334-351.

Studer, T. (1878). Uebersicht der Anthozoa Alcyonaria während der Reise S.M.S; "Gazelle" Um die Erde gesammelt wurden *Mber. akad. Wiss. Berlin*, 1878 : 632-688.

Templeton, R. (1835). Descriptions of a few invertebrated animals obtained at Ile de France. *Proc. Zool. Soc. Lond.* 1835 : 111.

Thomson, J.A. and MacKinnon, D. (1910). Alcyonarians collected by the Percy Sladen Trust Expedition by M.J. Stanley-Gardiner. 2. *Trans. Linn. Soc. Lond.*, (Zool.), 13 : 165-211.

Thomson, J.A. and Russel E.S. (1909). Alcyonarians collected by the Percy Sladen Trust Expedition by M.J. Stanley-Gardiner. 1. *Trans. Linn. Soc. Lond.*, (Zool.), 13 : 139-164.

Tixier-Durivault, A. (1956). Les Alcyonnaires du Museum. I. Famille des Alcyoniidae. 4. Genre *Lobophytum*. *Bull. Hist. nat., Paris* (ser. 2) 28 (4) : 401-405; 28 (5) : 476-482; 28 (6) : 541-546.

Tixier-Durivault, A. (1966). Faune de Madagascar. 21. Octocoralliaires. *Paris O.R.S.T.O.M.* : 456, 399 fig.

Tixier-Durivault, A. (1972). Nouvel apport d'Octocoralliaires de Madagascar et des Iles avoisinantes. *Tethys. suppl.,* 3 : 11-68.

Tixier-Durivault, A. and d'Hondt, M.J. (1974). Nouvelles récoltes d'Octocoralliaires à Madagascar. *Tethys* 5 : (2-3) 1973 : 251-266.

Wright, E.P. and Studer, Th. (1889). Report on the Alcyonaria collected by H.M.S. "Challenger" during years 1873-1876. *Sci. Rep. Voy. H.M.S. Challenger,* 31 : 341 pp.

ATOLL RESEARCH BULLETIN

NO. 205.

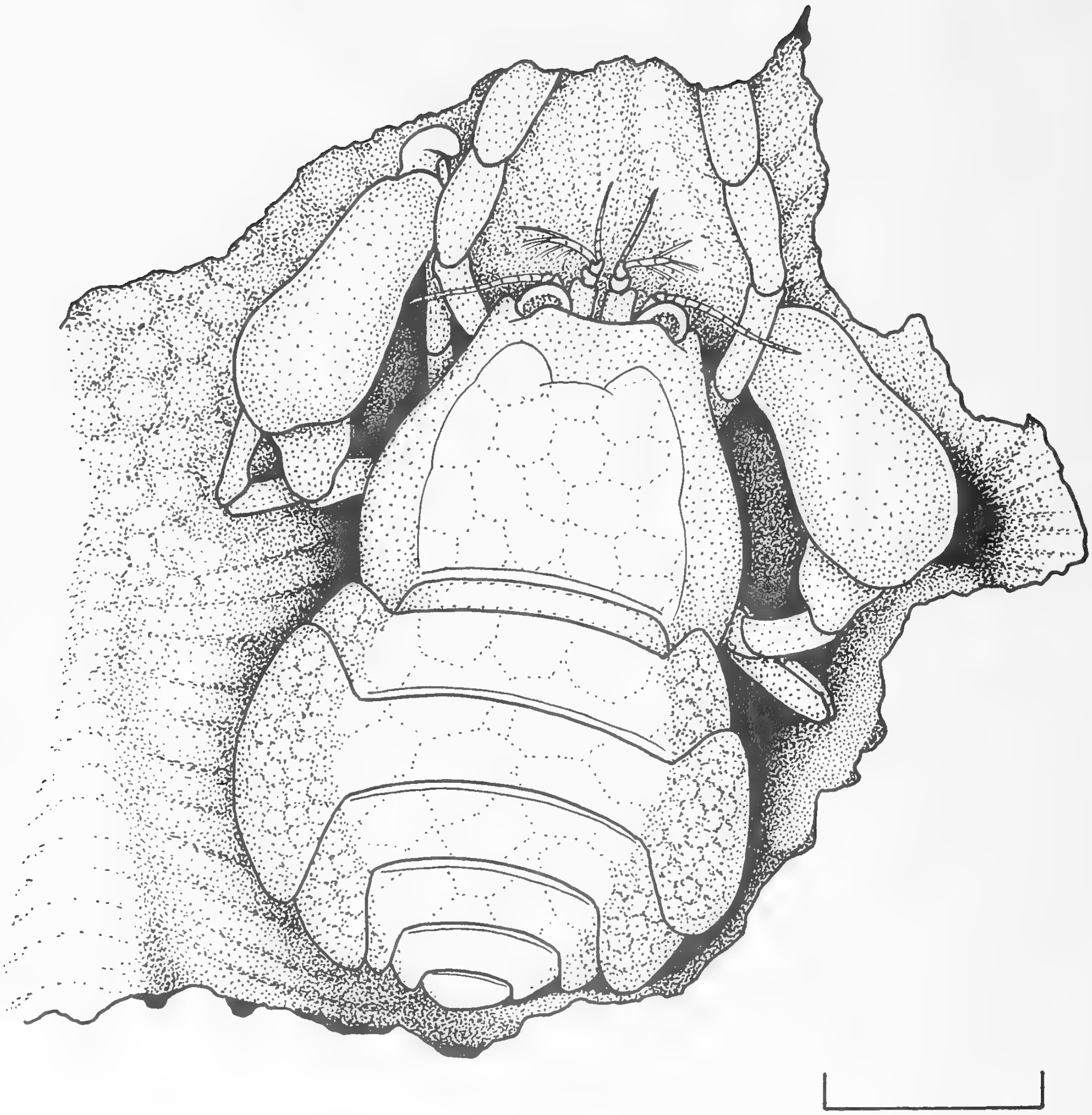
THE HOSTS OF THE CORAL-ASSOCIATED INDO-WEST-PACIFIC PONTONIINE SHRIMPS

by A. J. Bruce

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

February 1977

Paratypton siebenrocki Balss



Ovigerous female *in situ* in cyst in *Acropora* host coral, Mombasa, Kenya. Drawn from colour transparency, scale approximately 2 mm.

THE HOSTS OF THE CORAL-ASSOCIATED INDO-WEST-PACIFIC PONTONIINE SHRIMPS

by

A. J. Bruce[1]

Many of the shrimps belonging to the subfamily Pontoniinae Kingsley live in permanent obligatory association with scleractinian corals in the Indo-West Pacific region. These shrimps are abundant on most coral reefs and represent a major component of the diversity of the caridean fauna.

Borradaile (1917) mentioned briefly that shrimps of the genera *Harpiliopsis, Coralliocaris* and *Harpilius* (→*Periclimenes* spp., *Philarius* spp.) are adapted to life amongst the branches of coral colonies but provided no details. Kemp (1922) provided a list of associations of the Pontoniinae with corals, including again *Coralliocaris, Harpilius,* (in which he included *Harpiliopsis*), and *Periclimenes diversipes,* together with *P. spiniferus,* a free-living species frequently found in live or dead coral colonies. Holthuis (1952), in the report on the Pontoniinae collected by the Siboga and Snellius Expeditions, provided further details in tabular form of the species then considered to be associates of corals. The decapod fauna of the Queensland branching corals was analysed by Patton (1966), who added particularly to knowledge of the shrimps associated with the Pocilloporidae. The Proceedings of the Coral and Coral Reef Symposium, 1969, at Mandapam, included a review of the coral associations then known of the Indo-West Pacific Pontoniinae, with a key for their identification, and with further details of the *Acropora* host-species involved, (Bruce, 1972a).

The following report provides information on the coral species known to act as hosts for the obligatory shrimp associates. A number of other species may frequently be found when coral colonies are examined, i.e. *Palaemonella* spp. specially *P. rotumana* (Borradaile) and *Periclimenes petitthouarsi* (Audouin), and *P. spiniferus* De Man, and probably other related species. These species are free-living micro-predators or browsers. The exact identification of the hosts of some

---

[1] Formerly East African Marine Fisheries Research Organisation (EAMFRO).
(Manuscript received September 1975 --Eds.)

rare species, for example *Philarius lifuensis* (Borradaile), have yet to be ascertained, and it is probable that many more hosts of the known shrimp species, as well as new shrimps associated with new hosts, remain to be discovered.

SYSTEMATIC ACCOUNT

PALAEMONIDAE, Samouelle, 1819.

Pontoniinae, Kingsley, 1878..

1. *Vir orientalis* (Dana)

Restricted synonymy:
Vir orientalis- Bruce, 1972, 64, 65-67, fig.1.

Hosts. *Pocillopora damicornis* (L.) (Bruce, 1972a; 1972b).
Pocillopora verrucosa (Lam.) (Bruce, in press e).
Stylophora erythraea von Marenzeller (Bruce, 1972a).
Stylophora pistillata (Esper,) (Bruce, 1972a).
Acropora sp. (Bruce, in press, d, h).

Distribution. Sparsely recorded throughout the Indo-West Pacific region from East Africa to Hawaii.

Remarks. A small species that is easily overlooked and usually only present in small numbers in a host colony.

2. *Periclimenes amymone* De Man

Restricted synonymy:
Periclimenes amymone- Holthuis, 1972, 10, 82-83, fig.32.

Hosts. *Pocillopora damicornis* (L.) (Patton, 1966, 1974).
Stylophora mordax (Dana) (Patton, 1966).
Stylophora pistillata (Esper.) (Patton, 1966).
Seriatopora hystrix (Dana) (Patton, 1966).
Acropora cymbicyathus (Brooks) (Bruce, 1972a).
Acropora digitifera (Dana) (Bruce, 1972a).
Acropora diversa (Dana) (Bruce, 1972a)
Acropora eurystoma (Klunz.) (Bruce, 1972a).
Acropora hyacinthus (Dana) (Bruce, 1972a).
Acropora kenti (Brook) (Bruce, 1972a).
Acropora sarmentosa (Brook) (Bruce, 1972a).
Acropora syringodes (Brook) (Bruce, 1972a).
Acropora tenuis (Dana) (Bruce, 1972a).

Distribution. From Singapore and Djakarta in the west to Samoa in the east; not recorded from the Indian Ocean.

Remarks. One of the few commensal shrimps that is found commonly in both acroporid and pocilloprid coral hosts, where it is usually present on the outer branches.

3. *Periclimenes consobrinus* De Man

Restricted synonymy:
Periclimenes (Harpilius) lutescens- Holthuis, 1952, 12, 88-91, fig.35 (partim).
Periclimenes consobrinus - Bruce, 1975, 27, fig.16.

<u>Hosts</u>. *Pocillopora hemprichi* (Ehrenberg) (Bruce, 1971, as *P.lutescens*).
Pocillopora damicornis (L.) (Bruce, in press e).

<u>Distribution</u>. Due to confusion with the closely related *P. lutescens* auct. this species is known with certainty only from Ternate, Indonesia; the Comoro Islands, and Mombasa, Kenya.

<u>Remarks</u>. Bruce (1971) recorded the association of *P. lutescens* auct. with *Pocillopora hemprichi* in the Comoro Islands. At that time *P. consobrinus* was considered to be a synonym of *P. lutescens*, and the subsequent re-examination of the specimen showed that it should be correctly referred to *P. consobrinus* on account of the characteristic morphology of the second maxilliped (Bruce, 1972a, fig. 1b). This species is moderately common in the fringing lagoons of central East Africa, in *Pocillopora* sp., often also in association with *Harpiliopsis beaupresi, H. depressus* and *H. spinigerus*. It has not so far been found on any other host genus.

4. *Periclimenes lutescens* auct.

Restricted synonymy:

Periclimenes (Harpilius) lutescens - Holthuis, 1952, 12, 88-91, fig.35 (partim). Patton, 1966, 275, 288, tab.1. 290 tab.2.

Periclimenes lutescens - Bruce, 1971:2, 5; 1972a: 404, 405, 406, 407, 409, 410 fig.1a, 412 (key); 1975:27, fig.15.

<u>Hosts</u>. *Seriatopora hystrix* (Dana) (Patton, 1966).
Acropora convexa (Dana) (Bruce, 1972a).
Acropora humilis (Dana) (Bruce, 1972a).
Acropora kenti (Brooks) (Bruce, 1972a).
Acropora paniculata Verrill (Bruce, 1972a).
Acropora squarrosa (Ehrenberg) (Bruce, in press, d).
Acropora surculosa (Dana) (Bruce, 1973).
Acropora tubicinaria (Dana) (Bruce, in press, e).

<u>Distribution</u>. Widespread throughout the Indo-West Pacific region from the Red Sea to Madagascar, as far east as Tonga and Samoa, possibly extending to Tahiti and the Marquesas Islands.

<u>Remarks</u>. As noted under *P. consobrinus*, the report of an association of *P. lutescens* with *Pocillopora* in Bruce (1971) is erronous. This species is commonly found in association with *Jocaste* and *Coralliocaris* spp. The association of three specimens with *Seriatopora hystrix* reported from Heron Island by Patton (1966) is most unusual.

5. *Periclimenes parvus* Borradaile

Restricted synonymy:

Periclimenes parvus Borradaile, 1898:384; 1899:407, pl.36, fig.3.

<u>Hosts</u>. Unidentified.

<u>Distribution</u>. Known only from New Britain, the Makassar Straits and Singapore.

<u>Remarks</u>. The association of this species appears uncertain. Johnson (1961) notes that a single specimen from the Raffles Light, Singapore, in the Bedford Lanchester collection, was obtained from "outer coral" at very low tide. *Periclimenes parvus* possesses a biunguiculate dactylus on the ambulatory pereiopods (Holthuis, 1952), a feature that

is not found in any other coral associated pontoniine shrimp, and which suggests that the association may have been accidental. In coral-associated pontoniine shrimps this dactylus is generally robust and simple, except in *Fennera, Jocaste* and *Coralliocaris,* in which a basal process is present.

6. *Periclimenes diversipes* Kemp

Restricted Synonymy:

Periclimenes (Ancylocaris) diversipes Kemp, 1922:117, 169 (key), 179-184, figs. 36-39 (partim).

Hosts. *Psammocora togianensis* Umbgrove (Bruce, 1972a).
Pocillopora damicornis (L.) (Bruce, in press, e).
Stylophora erythraea von Marenzeller (Bruce, 1972a).
Seriatopora sp. (Bruce, 1971).
Acropora tenuis (Dana) (Bruce, 1972a).
Acropora variabilis (Klunzinger) (Bruce, in press, e).
Montipora circumvallata (Ehrenberg) (Bruce, 1971).
Montipora prolifera Breuggemann
Pavona danai (M.-Edw. & Haime) (Bruce, 1972a).
Porites nigrescens (Dana) (Bruce, in press, e).
Porites iwayamanensis Eguchi (Bruce, 1972a).
Porites sp.nov. cf. *andrewsi* (Bruce, 1972a).
Galaxea clavus (Dana) (Bruce, 1972c).

Distribution. Common in the Indian Ocean; from the Red Sea to Madagascar. Also recorded from the Australian Great Barrier Reef on *Acropora* sp. (Patton, 1966).

Remarks. The least host-specific of the pontoniine coral associates, with hosts belonging to nine different genera.

7. *Periclimenes madreporae* Bruce

Restricted synonymy:

Periclimenes madreporae Bruce, 1969:262-263, 264; 1972a:403, 404, 405, 406, 407, 409, 410, 413 (key). - Patton, 1974:221, 223-226 tab.1, 231, 239, 241 fig.1.

Periclimenes (Harpilius) inornatus Patton, 1966:274-275, 288 tab.2, 291 tab.3, fig.2. - Miyake & Fujino, 1968 400, 402 (key) 413-414, fig.3 g-h, 431 tab.1.

Hosts. *Pocillopora damicornis* (L.), (Patton, 1966).
Pocillopora verrucosa (Ellis & Solander) (Patton, 1966).
Seriatopora hystrix (Dana), (Patton, 1966).
Stylophora mordax (Dana), (Bruce, 1972a).
Stylophora pistillata (Esper.), (Patton, 1966).
Acropora corymbosa (Lam.), (Bruce, 1972a).
Acropora cuneata (Dana), (Bruce, 1972a).
Acropora digitifera (Dana), (Bruce, 1972a).
Acropora nasuta (Dana), (Bruce, 1972a).
Acropora rotumana (Gardiner), (Bruce, 1972a).
Turbinaria sp., (Bruce, 1972a).

Distribution. NE Australia, and Palau Islands only.

Remarks. The only caridean so far found in association with corals of the genus *Turbinaria*.

8. *Periclimenes holthuisi* Bruce

Restricted synonymy:

Periclimenes holthuisi Bruce, 1969:258-259.

Hosts. *Fungia actiniformis* Quoy & Gaimard.

Distribution. Zanzibar, Seychelle Is., Hong Kong, New Caledonia, and N.E. Australia.

Remarks. This species has generally been found in association with actiniarians, but it has also been found with scyphozoans (Bruce, 1972d). A pair of specimens were collected from the host at a depth of 60 ft. at Krantet Is., Madang, New Guinea, on 13-9-73 by J.E. Randall and R. Steene.

9. *Periclimenes mahei* Bruce

Restricted synonymy:

Periclimenes mahei Bruce, 1969:263-264; 1971:2, 11.

Hosts. *Pocillopora elongata* (Dana), host of type material, (Bruce, 1972a).

Seriatopora hystrix (Dana), (Bruce, 1971).

Acropora corymbosa (Lam.), (Bruce, in press, e).

Distribution. Known only from the Seychelle and Comoro Islands and Zanzibar.

Remarks. This species appears to occupy the same niche in the western Indian Ocean as *P. madreporae* does in the western Pacific Ocean.

10. *Periclimenes difficilis* Bruce

Periclimenes difficilis Bruce, (in press, e).

Hosts. *Porites nigrescens* Dana.

Distribution. Known only from the type locality on Praslin, Seychelle Islands.

Remarks. Closely related to *P. diversipes,* which is the only other species of this genus known to associate with corals of the genus *Porites*.

11. *Periclimenes kororensis* Bruce

Periclimenes kororensis Bruce, (in press, f).

Hosts. *Fungia actiniformis* Quoy & Gaimard.

Distribution. Known only from the type locality on Koror, Palau Islands.

Remarks. A rather aberrant species of *Periclimenes,* known only from the incomplete holotype specimen.

12. *Periclimenes gonioporae* Bruce

Periclimenes gonioporae Bruce, (in press, b).

Hosts. *Goniopora stokesi* Milne Edwards & Haime.

Lobophyllia sp.

Distribution. Known only from fringing lagoons of southern Kenya.

Remarks. Closely related to *P. mahei* and *P. diversipes,* but appears to be specially associated with the genus *Goniopora*.

13. *Philarius gerlachei* (Nobili)

Restricted synonymy:

Harpilius gerlachei Kemp, 1922:299 (key), 238-239, figs.74-75.

Hosts. *Acropora corymbosa* (Lam.), (Bruce, in press, e).
Acropora cymbicyathus (Brooks)
Acropora digitifera (Dana), (Bruce, 1972a)
Acropora formosa (Dana), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora hyacinthus (Dana), (Bruce, 1972a).
Acropora nana (Studer), (Bruce, 1972a).
Acropora surculosa (Dana), (Bruce, 1973).

Distribution. From the Red Sea, East Africa and Madagascar to the Marshall, Gilbert and Samoan Islands.

Remarks. Distinctly less common, in the *Acropora* hosts, than *Jocaste* or *Coralliocaris* species.

14. *Philarius imperialis* (Kubo)

Restricted synonymy:
Harpilius imperialis Kubo, 1940: 1-4, figs. 1-3.

Hosts. *Acropora* spp., (Bruce, 1972a).

Distribution. From the Red Sea to Zanzibar, as far east as the Palau and Marshall Islands.

Remarks. Generally uncommon; particularly in comparison with *Jocaste* and *Coralliocaris* spp. Usually found right at the very innermost bases of the branches of the coral hosts, often on the floor of the grooves between branches. The colour pattern of this species shows the closest resemblance to the illustration given by Dana (1855, pl.37 fig.4) of *Harpilius lutescens*. This species is apparently found in a variety of *Acropora* host species, but none have been identified to specific level.

15. *Philarius lifuensis* (Borradaile)

Restricted synonymy:
Periclimenes lifuensis Borradaile, 1898:384; 1899:405, pl.36 fig.1.

Hosts. *Acropora* sp. (Bruce, 1972a).

Distribution. Recorded only from the type locality in the Loyalty Islands.

Remarks. The rarest species of this genus. Additional material has also been recently obtained from Heron Island and Erskine Island, Queensland, Australia.

16. *Hamopontonia corallicola* Bruce

Restricted synonymy:
Hamopontonia corallicola Bruce, 1970: 38-48, figs. 1-4.

Hosts. *Fungia actiniformis* Quoy & Gaimard, (Bruce, in press, c).
Goniopora stokesi Milne-Edwards & Haime (Bruce, 1970).

Distribution. Known only from Hong Kong and Queensland Australia.

Remarks. The colouration of specimens found in association with the *Fungia* is generally similar to that of the type material on *Goniopora*, although the specimens are distinctly larger in size. Mortensen (1925, in: Balss, 1956) refers to a shrimp from the Kei Islands, which lives among the white tipped tentacles of a *Fungia* coral, and which is colourless with two white spots on carapace, which almost certainly belongs to this species.

17. *Ischnopontonia lophos* (Barnard)

Restricted synonymy:

Philarius lophos Barnard, 1962:242-243, fig.2.

Ischnopontonia lophos-Bruce, 1966:585-597, figs. 1-5.

Hosts. *Galaxea fascicularis* (L.), (Bruce, 1966).

Distribution. Common in the western Indian Ocean; also Singapore; Pulau Perhentian Besar, Malaysia and Queensland, Australia.

Remarks. This species apparently strictly associated with this single coral host type, where it is often found with *Platycaris latirostris* and occasionally with *Anapontonia denticauda*. The species is remarkable for its particularly strongly bilaterally compressed body form, and it moves actively in the spaces between the host corallites.

18. *Anapontonia denticauda* Bruce

Restricted synonymy:

Anapontonia denticauda Bruce, 1967:8-12, figs.1-4.

Hosts. *Galaxea fascicularis* (L.), (Bruce, 1967)

Distribution. Known only from Zanzibar; Singapore; Pulau Perhentian Besar, Malaysia and Queensland, Australia.

Remarks. Of the three species of pontoniine shrimps restricted to this host, *Anapontonia denticauda* is the least common.

19. *Metapontonia fungiacola* Bruce

Restricted synonymy:

Metapontonia fungiacola Bruce, 1967:24-30, figs.9-12.

Hosts. *Fungia* spp. (Bruce, 1967).
Halomitra sp. (Bruce, in press, h).
Hydnophora microconus Lam. (Bruce, 1972e).
Goniastrea pectinata (Ehrenberg) (Bruce, 1974b).

Distribution. Known only from the western Indian Ocean: Kenya, Tanganyika and the Comoro and Seychelle Islands.

Remarks. One of the smallest pontoniine shrimp species. The species of *Fungia* with which this shrimp has been found to associate have so far not included *Fungia actiniformis*, which does not occur in the region where *M. fungiacola* has been found.

20. *Platycaris latirostris* Holthuis

Restricted synonymy:

Platycaris latirostris Holthuis, 1952:16, 173-176, figs. 85-86.

Hosts. *Galaxea fascicularis* (L.) (Bruce, 1966).

Distribution. Common in the western Indian Ocean; Flores, Indonesia.

Remarks. This species appears to be strictly associated with this single host species. It is remarkable for its strongly depressed body form. It is sluggish in behaviour, resting in a head down position on the corallites.

21. *Paratypton siebenrocki* Balss

Restricted synonymy:

Paratypton siebenrocki - Bruce, 1969:171-185, figs. 1-5, pl.1 a-c.

Hosts. *Acropora hyacinthus* (Dana) (Bruce, 1972).
Acropora massawensis von Marenzeller (Bruce, in press, e).
Acropora palmerae Wells (Bruce, 1972a).
Acropora squamosa Brook (Bruce, 1972a).
Acropora squarrosa (Ehrenberg) (Bruce, 1972a).
Acropora variabilis (Klunzinger) (Bruce, 1974b).

Distribution. Recorded from the Red Sea, Kenya, Tanganyika and Zanzibar, the Seychelle Islands, Marshall and Samoan Islands and Heron Island, Australia.

Remarks. This species is remarkable for its habit of living in pairs in small cysts completely enclosed by the host's corallum with only a few minute apertures connecting the chamber with the exterior.

22. *Fennera chacei* Holthuis

Restricted synonymy:
Fennera chacei Holthuis, 1951: 171-178, pl.54 a-p. Bruce, 1965: 80-82, fig.1; 1974b: 195, fig.4.

Hosts. *Pocillopora verrucosa* (Ellis & Solander), (Patton, 1966).
Pocillopora eydouxi Milne-Edwards & Haime, (Bruce, 1965).

Distribution. Kenya, Maldive and Seychelle Islands and Willis Island, off NE Australia.

Remarks. One of the smallest pontoniine shrimps. It may be found on the same host colonies with *Harpiliopsis depressus* and *H. spinigerus*. Originally discovered in the eastern Pacific region on the shores of Mexico, Costa Rica, Panama and Colombia, on *Porites*.

23. *Harpilius beaupresi* (Audouin)

Restricted synonymy:
Harpiliopsis beaupresi Borradaile, 1917: 324, 379, pl.55, fig.21. Kemp, 1922: 229-231, figs. 67-68.

Hosts. *Pocillopora acuta* Lamarck, (Bruce, 1972a).
Pocillopora damicornis (L.) (Patton, 1966).
Pocillopora danae (Verrill), (Bruce, 1972a).
Pocillopora elongata (Audouin), (Bruce, 1972a).
Pocillopora eydouxi Milne-Edwards & Haime, (Bruce, 1972a).
Pocillopora verrucosa (Ellis & Solander), (Patton, 1966).
Pocillopora woodjonesi Vaughan, (Bruce, 1972a).
Seriatopora hystrix (Dana), (Patton, 1966).
Stylophora erythraea von Marenzeller, (Bruce, 1972a).
Stylophora mordax (Dana), (Bruce, 1972a).
Stylophor palmata (Blainville), (Bruce, 1974b).
Stylophora pistillata (Esper.), (Bruce, 1972a).
Acropora variabilis (Klunzinger), (Bruce, 1972a).

Distribution. Widespread throughout the Indo-West Pacific region from the Red Sea to Mocambique and Madagascar as far east as Hawaii; also extending into the East Pacific region.

Remarks. One of the commonest pontoniine coral commensals, frequently found in association with *H. depressus* and *H. spinigerus*.

24. *Harpiliopsis depressus* (Ortmann)

Restricted synonymy:

Harpilius depressus Stimpson, 1860:38. Kemp, 1922:228 (key), 231-234, figs. 69-70.

Harpiliopsis depressus Borradaile, 1917: 379 (key), 380. Holthuis, 1951:70-75, pls.21-22; 1952:16, 182-184, fig.90.

Hosts. *Pocillopora damicornis* (L.) (Bruce, 1972a)*
Pocillopora elongata Dana, (Bruce, 1972a).
Pocillopora eydouxi Milne-Edwards & Haime, (Bruce, 1972a).
Pocillopora ligulata (Dana), (Chace, 1937).
Pocillopora meandrina var. *nobilis* Verrill (Castro, 1971).
Pocillopora verrucosa (Ellis & Solander), (Patton, 1966)*
Pocillopora woodejonesii Vaughan (Bruce, 1972a).
Seriatopora angulata Klunzinger, (Bruce, 1972a).
Seriatopora hystrix (Dana), (Patton, 1966).
Stylophora mordax (Dana) (Patton, 1966).
Stylophora pistillata (Esper.), (Patton, 1966).
Acropora sp. (Bruce, 1972a).
Porites sp. (Holthuis, 1951).

Distribution. Widespread throughout the whole Indo-West Pacific region from the Red Sea to Madagascar as far east as Hawaii and in the East Pacific to the Galapagos Islands, California, Mexico, Costa Rica, Panama and Colombia.

Remarks. One of the commonest pontoniine coral commensals, frequently found in mixed association with *H. beaupresi* and *H. spinigerus*. Juveniles of this species have also been collected on one occasion from a colony of the hydrozoan *Millepora* sp. There has been considerable confusion in the zoological literature between this species and *H. spinigerus* and many of the records are of dubious value. Those indicated with an asterisk have been recently confirmed. The *P. ligulata* record is from the East Pacific region.

25. *Harpiliopsis spinigerus* (Ortmann)

Restricted synonymy:

Anchistus spinigerus Ortmann, 1890:511, pl.36 fig.23.

Harpilius depressus var. *gracilis* Kemp, 1922:228 (key), 234-235, fig.71.

Harpiliopsis depressus var. *spinigerus* Holthuis, 1952:16 184-185.

Harpiliopsis spinigerus Bruce, 1974:224; (in press, d).

Hosts. *Pocillopora eydouxi* Milne-Edwards & Haime, (Bruce, in press, j).
Pocillopora verrucosa (Ellis & Solander), (Bruce, 1974).
Stylophora mordax (Dana), (Bruce, in press, d).
Stylophora palmata (Blainville), (Bruce, in press, e).
Stylophora pistillata (Esper.), (Bruce, in press, e).

Distribution. Known with certainty only from Kenya, Farquhar Island, the Andaman Islands, Celebes and Samoa.

Remarks. Some of the host records given under *H. depressus* probably refer to this species, which appears to be common and widespread probably throughout the whole Indo-West Pacific region.

26. *Cavicheles kempi* Holthuis

Restricted synonymy:

Cavicheles kempi Holthuis, 1952:17, 205-208, figs. 99-101. Bruce, 1966:266-269, figs.1-2.

Hosts. *Acropora* sp., (Bruce, 1966; in press, h).

Distribution. Recorded only from Halmahera, the Molucca Archipelago; Kenya, Zanzibar and Tanganyika; and the Comoro Islands.

Remarks. The East African and Comoro Islands material was found in *Acropora* colonies generally in association with numerous specimens of *Jocaste* spp. and it is considered probable that this species is a post-larval or early juvenile of *J. japonica* (Ortmann).

27. *Jocaste japonica* (Ortmann)

Restricted synonymy:

Jocaste japonica-Patton, 1966:279-280, 288 tab.1, 290 tab.2, fig.3b. Bruce, 1974b:198-199, fig.7.

Hosts. *Pocillopora damicornis* (L.), (Bruce, 1972a).
Acropora abrotanoides (Lam.), (Bruce, in press, e).
Acropora assimilis (Brook), (Bruce, in press, e).
Acropora convexa (Quelch), (Bruce, 1972a).
Acropora corymbosa (Lam.), (Bruce, in press, e).
Acropora digitifera (Dana), (Bruce, 1972a).
Acropora disticha (Brook), (Bruce, in press, e).
Acropora diversa (Dana), (Bruce, 1972a).
Acropora haimei (Milne-Edwards & Haime), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora massawensis (von Marenzeller), (Bruce, in press, e).
Acropora nana (Studer), (Bruce, 1972a).
Acropora nasuta (Dana), (Bruce, 1972a).
Acropora pectinata (Brook), (Bruce, in press, h).
Acropora rotumana (Gardiner), (Bruce, 1972a).
Acropora spicifera (Dana), (Bruce, in press, h).
Acropora squamosa (Brook), (Bruce, 1972a).
Acropora squarrosa (Ehrenberg), (Bruce, in press h).
Acropora surculosa (Dana), (Bruce, 1973).
Acropora valida (Dana), (Bruce, in press e).
Acropora variabilis (Klunzinger), (Bruce, 1972a, 1974b).

Distribution. Widespread throughout most of the Indo-West Pacific region, but not recorded from the Red Sea, Arabian Sea or Bay of Bengal, nor east of the Marshall Islands.

Remarks. Some reports of *J. lucina* may refer to this species. The reference to an association of this shrimp with *Acropora tenuis*, (Bruce, 1972a) was erroneous due to misidentification. As noted above, *Cavicheles kempi* is probably a juvenile stage of this species.

28. *Jocaste lucina* (Nobili)

Restricted synonymy:

Jocaste lucina - Patton, 1966:278-279, 288 tab.1, 290 tab.2, 292, fig.3a. Bruce, 1974b:199, fig.8.

Hosts. *Pocillopora verrucosa* (Ellis & Solander), (Patton, 1966).
Stylophora sp.
Acropora conferta (Quelch), (Bruce, 1972a).

Acropora corymbosa (Lam.), (Bruce, 1972a).
Acropora cuneata (Dana), (Bruce, 1972a).
Acropora eurystoma (Klunzinger), (Bruce, in press, j).
Acropora haimei (Milne-Edwards & Haime), (Bruce, in press, e).
Acropora hebes (Dana), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora palifera (Lam.), (Bruce, 1972a).
Acropora ramiculosa (Dana), (Bruce, 1972a).
Acropora squamosa (Brook), (Bruce, 1972a).
Acropora tenuis (Dana), (Bruce, 1972a).
Acropora teres (Verrill).
Acropora variabilis (Klunzinger), (Bruce, 1972a).
Porites sp.

Distribution. Throughout the Indo-West Pacific region, except the Hawaiian Islands.

Remarks. The associations of *Jocaste* spp. with *Acropora* spp. has been reviewed by Bruce (1969c). Details were provided of eighteen host species with *J. jocaste* exclusively associated with eleven species, *J. lucina* with ten and three coral species, *A. humilis, A. squamosa* and *A. variabilis* acting as hosts for both shrimp species. The number of *Acropora* species now known to serve as hosts for *Jocaste* spp., is now increased to twenty nine, with fifteen exclusively for *J. japonica,* nine for *J. lucina,* and with the addition of two species, *A. corymbosa* and *A. haimei,* to those hosting both species of shrimps. The two specimens found in association with *Porites* are juvenile, but those with *Stylophora* were adult (11, 4 ovig.) and were associated with *Coralliocaris* and *Harpiliopsis* spp.

29. *Coralliocaris brevirostris* Borradaile

Restricted synonymy:
Coralliocaris brevirostris Borradaile, 1898:1006, pl.64, fig.7. Bruce, 1972a:405, 406, 407, 415 (key), fig.2c.

Hosts. *Acropora corymbosa* (Lam.), (Bruce, 1972a).
Acropora cymbicyathus (Brooks).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora hyacinthus (Dana).

Distribution. Known only from the Ellice Islands, and Willis Island, NE Australia.

Remarks. The specimen from Mauritius, referred to *C. brevirostris* by Holthuis (1965), should be referred to *C. nudirostris* Heller. The chelae of the second pereiopods in *C. nudirostris* show a close resemblance to *C. brevirostris,* rather than *C. venusta*.

30. *Coralliocaris graminea* (Dana)

Restricted synonymy:
Coralliocaris graminea - Holthuis, 1952:17, 186-189, fig.91.

Hosts. *Pocillopora danae* (Verrill), (Bruce, 1972a).
Pocillopora elongata Dana, (Bruce, 1972a).
Seriatopora hystrix (Dana), (Patton, 1966).
Stylophora erythraea von Marenzeller, (Bruce, 1972a).
Acropora corymbosa (Lam.), (Bruce, 1972a).
Acropora cymbicyathus (Brooks), (Bruce, 1972a).

Acropora digitifera (Dana), (Bruce, in press, e).
Acropora diversa (Dana), (Bruce, 1972a).
Acropora haimei (Milne-Edwards & Haime), (Bruce, 1972a).
Acropora hebes (Dana), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora nana (Studer), (Bruce, 1972a).
Acropora nasuta (Dana), (Bruce, 1972a).
Acropora ramiculosa (Dana), (Bruce, 1972a).
Acropora squamosa (Brooks), (Bruce, 1972a).
Acropora squarrosa (Ehrenberg), (Bruce, in press, e).
Acropora variabilis (Klunzinger), (Bruce, 1972a).

Distribution. Probably common throughout the whole Indo-West Pacific region except for the Hawaiian Islands.

Remarks. Many of the records of *C. graminea* probably refer to *C. viridis,* and similarly some of the host records may also refer to this species. Although these two closely related species may be found in the same localities, they do not occur together on the same coral host colonies, as may occur in the species-pair *Harpiliopsis depressus* and *H. spinigerus*. Specimens from *Seriatopora* and *Stylophora* are usually small juveniles and these genera must be regarded as abnormal hosts.

31. *Coralliocaris macrophthalma* (Milne-Edwards)

Restricted synonymy:
Coralliocaris macrophthalma - Borradaile, 1898:385. Nobili, 1901:3.

Hosts. Probably *Acropora* spp., but none so far recorded.

Distribution. Known only from "Mers d'Asie", the Red Sea and the Seychelle Islands.

Remarks. This little known species is most closely related to *C. graminea* and *C. viridis,* with sound-producing chelae on the second pereiopods.

32. *Coralliocaris nudirostris* (Heller)

Restricted synonymy:
Oedipus nudirostris Heller, 1862:279, pl.3 fig.25.
Coralliocaris nudirostris - Borradaile, 1971:382 (key), 384
Bruce, 1974c:262, fig.2.

Hosts. *Acropora digitifera* (Dana), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora hyacinthus (Dana), (Bruce, 1972a).
Acropora spicifera (Dana), (Bruce, press, h).
Acropora surculosa (Dana), (Bruce, 1973).

Distribution. Reported only from the Red Sea, Tanganyika, the Seychelle and Maldive Islands and Tahiti.

Remarks. On East African fringing reefs, this species seems to prefer hosts situated on the exposed side of the reef crest rather than the lagoon side.

33. *Coralliocaris pavonae* Bruce

Restricted synonymy:
Coralliocaris pavonae Bruce, 1972:63, 77-84, figs. 8-11.

Coralliocaris taiwamensis Fujino & Miyake, 1972:95-98, figs.1-2.

Hosts. *Pavona divaricata* (Lam.), (Bruce, 1972a)
Pavona minor Breuggemann, (Bruce, 1972a).

Distribution. Known from Fiji and Taiwan only.

Remarks. The only species of the genus that is apparently normally associated with a coral host not belonging to the genus *Acropora*.

34. *Coralliocaris superba* (Dana)

Restricted synonymy:
Coralliocaris superba - Holthuis, 1952:17, 189-191, fig.92.

Hosts. *Pocillopora danae* (Verrill), (Bruce, 1972a)
Acropora africana (Brooks), (Bruce, in press, h).
Acropora convexa (Dana), (Bruce, in press, e).
Acropora cymbicyathus (Brooks), (Bruce, 1972a).
Acropora digitifera (Dana), (Bruce, 1972a)
Acropora disticha (Brooks), (Bruce, in press, h).
Acropora diversa (Dana), (Bruce, 1972a).
Acropora eurystoma (Klunzinger), (Bruce, 1972a).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora irregularis (Brooks), (Bruce, 1972a).
Acropora leptocyathus (Brooks), (Holthuis, 1953).
Acropora nana (Studer), (Bruce, 1972a).
Acropora nasuta (Dana), (Bruce, in press, h).
Acropora pectinata (Brooks), (Bruce, in press, h).
Acropora pulchra (Brooks), (Bruce, 1972a).
Acropora variabilis (Klunzinger), (Bruce, in press, h).

Distribution. Widespread throughout the Indo-West Pacific region from the Red Sea to Madagascar as far east as Tahiti and the Society Islands.

Remarks. Five of the host corals also serve as hosts for *C. "graminea"*. This species is one of the most beautifully coloured of pontoniine coral commensals (Bruce, 1974c, fig.3), and was accurately illustrated by Dana (1855, pl.37 fig.2).

35. *Coralliocaris venusta* Kemp

Restricted synonymy:
Coralliocaris venusta Kemp, 1922:269, 274-276, figs.100-101.

Hosts. *Acropora convexa* (Dana), (Bruce, 1972a).
Acropora cymbicyathus (Brooks).
Acropora humilis (Dana), (Bruce, 1972a).
Acropora hyacinthus (Dana).
Acropora subulata (Dana), (Bruce, in press, h).
Acropora pectinata (Brooks), (Bruce, in press, h).

Distribution. Red Sea, central East Africa, the Seychelle Islands, Mocambique Channel, Indonesia, the South China Sea, Samoa and the Great Barrier Reef.

Remarks. It has been noted (Bruce, in press, h), that two distinct species have probably been confused under this name. The two "species" are readily separated by their distinct colour patterns in life, but no satisfactory morphological distinction has yet been found.

36. *Coralliocaris viridis* Bruce

Restricted synonymy:

Coralliocaris viridis Bruce, 1974a:222-224, fig.1 a-b.

Hosts. *Acropora disticha* (Brooks), (Bruce, in press, h).
Acropora humilis (Dana), (Bruce, in press, h).
Acropora valida (Dana), (Bruce, in press, h).
Acropora variabilis (Klunzinger), (Bruce, in press, h).

Distribution. Known only from southern Kenya, the Mocambique Channel and the Great Barrier Reef. Probably throughout the Indo-West Pacific region.

Remarks. Many records of the closely related *C. graminea* probably refer to this species.

37. *Pontonides maldivensis*(Borradaile)

Restricted synonymy:

Pontonides maldivensis - Borradaile, 1917:387, pl.57 fig.28.

Host. *Dendrophyllia micracantha* (Ehrenberg), (Bruce, in press, h).

Distribution. Known only from the Maldive Islands and Mombasa, Kenya.

Remarks. This species and the next are the only known commensals of a-hermatypic corals.

38. *Pontonides unciger* Calman

Restricted synonymy:

Pontonides unciger - Holthuis, 1952:219-223, fig.108-110.

Host. *Dendrophyllia ijimae* Yabe & Eguchi, (Fujino & Miyake, 1969).

Distribution. Reported from the Red Sea; Amakusa Islands, Japan, and Indonesia.

Remarks. Other species of the genus *Pontonides* have been found to associate with gorgonian or antipatharian hosts.

Discussion

Details are given of thirty seven species of Indo-West Pacific pontoniine shrimps that are considered to be obligate commensals of scleractinian corals. The criteria for assessing the obligate nature of the association have been provided by Garth (in press), who indicated that the shrimps concerned are not found away from their host, that the association in recurrent, and that adult breeding individuals are involved. One species, *Periclimenes parvus,* is considered to be a doubtful coral-associate. Fourteen genera, out of a present total of forty-three known Indo-West Pacific pontoniine genera, have now been found to have some species living in association with corals and of these genera, nine are monospecific. One of these monospecific genera, *Vir* Holthuis, is one of the least specialized pontoniine genera, with an unmodified set of palaemonid mouthparts, including a mandible with a small palp. The eight other nonospecific genera consist of highly specialized species, showing an increasing degree of reduction of many parts of the mouthparts.

The hosts are represented by seventy-six different species, of seventeen genera, although forty-one of these belong to the genus

Acropora alone and sixteen to the branching corals of the families Thamnasteridae (*Pocillopora, Seriatopora* and *Stylophora*). The Acroporidae (*Acropora* spp.) clearly provide the most satisfactory niches for these shrimps. It is certain that many hosts still remain to be identified, especially those from the reef front and from deeper water, as most of the records have been derived from shallow lagoons or pools on the reef flats easily accessible at low tide.

The most favoured host coral is *Acropora humilis* (Dana). This species has been found to provide a niche for a *Periclimenes,* a *Philarius,* two *Jocaste* and six *Coralliocaris* species. Although these do not occur all on a single host colony, it is not uncommon to find *Periclimenes lutescens* with two *Jocaste* and two *Coralliocaris* spp. together in a single host. Similarly, *Pocillopora damicornis* (L.) may act as host for *Vir orientalis,* three *Periclimenes* and two *Harpiliopsis* spp. The number of species and individuals present in a coral colony is largely dependant upon the size of the colony, small colonies often having only a single male-female pair of one species. Large corals may have over a hundred individual shrimps (Bruce, 1972a).

The abundance of coral-associated pontoniine shrimps in the Indo-West Pacific region is in marked contrast with findings in other tropical seas (Bruce, in press, g). Of the genera associated with corals in the Indo-West Pacific region, only *Periclimenes* is found to occur elsewhere and none of its extra-Indo-West Pacific species are reported to be specifically associated with corals, although the hosts of several species that are possibly commensals remain to be ascertained. In the Eastern Pacific region two species of pontoniine shrimps, *Harpilius depressus* and *Fennera chacei,* are known to live in association with coral hosts. Both these species are of widespread distribution and have probably extended their ranges across the East Pacific barrier, via the Galapagos Islands, by means of the Equatorial Counter Current. In the Caribbean region there are no reported associations between pontoniine shrimps and corals and even the *Acropora* species, which provide a niche for so many of the Indo-West Pacific species, are without a similar series of faunal associates.

Acknowledgements

For the identification of many of the coral hosts here reported, I am particularly endebted to P.M.J. Woodhead, Dr. B.R. Rosen, Dr. J.W. Wells and Dr. H. Utinomi.

References

Barnard, K.H. 1962. New records of marine Crustacea from the East African region. *Crustaceana,* 3:239-245, figs.1-2.

Borradaile, L.A. 1898. On some Crustaceans from the South Pacific, Part III. Macrura. *Proc.zool.Soc.Lond.,* 1898:1000-1015, pls.63-65.

Borradaile, L.A. 1899. On the Stomatopoda and Macrura brought by Dr. Willey from the South Seas. In: Willey, A., *Zoological Results based on Material from New Britain, New Guinea, Loyalty Islands and elsewhere, collected during the years 1895, 1896 and 1897*, 4:395-428, pls.36-39.

---------- 1917. On the Pontoniinae. The Percy Sladen Trust Expedition to the Indian Ocean in 1905, under the leadership of Mr. J. Stanley Gardiner. *Trans.Linn.Soc.Lond.,* (2) 17:323-396, pls. 52-57.

Bruce, A.J. 1965. On the occurrence of *Fennera chacei* Holthuis (Crustacea Decapoda Natantia, Pontoniinae) in the Indian Ocean. *J.Mar.biol.Ass.India,* 7(1):80-82, fig.1.

---------- 1966a. Notes on some Indo-Pacific Pontoniinae. XI. A re-examination of *Philarius lophos* Barnard, with the designation of a new genus *Ischnopontonia*. *Bull.mar.Sci.* 16(3):584-598, figs.1-5.

---------- 1966b. The re-discovery of *Cavicheles kempi* Holthuis (Decapoda Natantia, Pontoniinae) in the Comores. *Bull.Mus.nat. Hist.Nat.Paris,* (2) 38 (3):266-269, fig.1.

---------- 1966c. Notes on some Indo-Pacific Pontoniinae, II. *Platycaris latirostris* Holthuis. *Crustaceana,* 11 (1):1-9, figs. 1-5.

----------1967. Notes on some Indo-Pacific Pontoniinae, III-IX. Descriptions of some new genera and species from the western Indian Ocean and South China Sea. *Zool.Verhand.Leiden,* 87:1-73, figs.1-29.

---------- 1969a. Notes on some Indo-Pacific Pontoniinae. XIV. Observations on *Paratypton siebenrocki* Balss. *Crustaceana,* 17 (2):170-186, figs.1-5, pl.1.

---------- 1969b. Preliminary descriptions of sixteen new species of the genus *Periclimenes* Costa, 1844 (Crustacea, Decapoda Natantia, Pontoniinae). *Zool.Meded.Leiden,* 43 (20):253-278.

---------- 1969c. Observations upon the host-specificity and distribution of *Jocaste japonica* (Ortmann) and *Jocaste lucina* (Nobili) (Decapoda Natantia, Pontoniinae). *Crustaceana,* 17 (3):298-302, figs.1-2.

---------- 1970a. Notes on some Indo-Pacific Pontoniinae. XV. *Hamopontonia corallicola* gen. nov., sp. nov., a new pontoniinid shrimp from Hong Kong. *Crustaceana,* 18 (1):37-48, figs.1-4.

Bruce, A.J. 1970b. On the identity of *Periclimenes pusillus* Rathbun 1906. (Decapoda, Pontoniinae). *Crustaceana,* 19 (3):306-310, fig.1.

---------- 1971. Pontoniinid shrimps from the Ninth Cruise of the R/V Anton Bruun, IIOE, 1964:I. *Palaemonella* Dana and *Periclimenes* Costa. *Smithsonian Contrib.Zool.,* 82:1-13, fig.1.

---------- 1972a. A review of information upon the coral hosts of commensal shrimps of the subfamily Pontoniinae, Kingsley, 1878. (Crustacea Decapoda, Palaemonidae). *Proc.Symp.Corals and Coral Reefs, 1969* (Mar.biol.Ass.India), 339-418, figs.1-2.

---------- 1972b. A Report on a Small Collection of Pontoniinid Shrimps from Fiji, with a description of a new species of *Coralliocaris* Stimpson. *Pacific Sci.,* 26 (1):63-86, figs.1-11.

---------- 1972c. On the association of the shrimp *Racilius compressus* (Decapoda, Alpheidae) with the coral *Galaxea clavus* (Dana) *Crustaceana,* 22 (1):92-93.

---------- 1972d. An association between a pontoniinid shrimp and a rhizostomatous scyphozoan. *Crustaceana,* 23 (3): 300-302.

---------- 1972e. The occurrence of the shrimp *Metapontonia fungiacola* Bruce (Crustacea, Decapoda, Pontoniinae) in Kenyan waters. *J.East African Nat.Hist.Soc.Nat.Mus.,* 134:1-5, fig.1., pls.1-2.

---------- 1973. Notes on some Indo-Pacific Pontoniinae, XXIII. *Tectopontonia maziwiae* gen.nov., sp.nov., a new coral associate from Tanganyika (Decapoda Palaemonidae). *Crustaceana,* 24 (2): 169-180, figs.1-4.

---------- 1974a. *Coralliocaris viridis* sp.nov., a preliminary note, (Decapoda Natantia, Pontoniinae). *Crustaceana,* 26 (1):222-224, fig.1.

---------- 1974b. A report on a small collection of pontoniinid shrimps from the Island of Farquhar. *Crustaceana,* 27 (2):189-203, figs. 1-8.

---------- 1974c. Hidden Shrimps of Coral Reefs. *Wildlife,* 16 (2): 260-263, figs.1-6.

---------- 1975. Coral reef shrimps and their colour patterns. *Endeavour,* 34:23;27, figs.1-16.

---------- in press a. Coral Reef Caridea and "commensalism". Micronesica.

---------- in press b. *Periclimenes gonioporae* sp.nov., a new pontoniinid shrimp from Kenya. *J.E.A.Trop.Fish.Hydrobiol.*

Bruce, A.J. In press c. A report on a small collection of pontoniinid shrimps from Queensland, Australia. *Crustaceana.*

---------- in press d. A report on a small collection of shrimps from the Kenya National Marine Parks at Malindi, with notes on selected species. *Zool.Verhand.Leiden.*

---------- in press e. A report on some pontoniinid shrimps collected from the Seychelle Islands by the F.R.V. Manihine, 1972, with a review of the Seychelle pontoniinid shrimp fauna. *J.Linn.Soc. Lond., Zool.*

---------- in press f. *Periclimenes kororensis* sp.nov., an unusual new pontoniinid shrimp from Koror, Palau Islands. *Micronesica.*

---------- in press g. Shrimps and Prawns of Coral Reefs, with special reference to commensalism. In: O.A. Jones and R. Endean, eds: *Biology and Geology of Coral Reefs,* 3 (2): 37-94, figs.1-21.

---------- in press h. A synopsis of the pontoniinid shrimp fauna of Central East Africa. *J.Nat.Hist.*

Castro, P. 1971. The Natantian Shrimps (Crustacea, Decapoda) associated with Invertebrates in Hawaii. *Pacific Sci.,* 25: 395-403.

Chace, F.A., JR. 1937. Caridean Decapod Crustacea from the Gulf of California and the West Coast of Lower California. The Templeton-Crocker Expedition. VII. *Zoologica, N.Y.,* 22:109-138, figs.1-9.

Dana, J.D. 1855. *Crustacea. United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842 under the Command of Charles Wilkes, U.S.N.,* 13: *Atlas,* 1-27, pls.1-96.

Fujino, T. and Miyake, S. 1969. Sexual dimorphism and variation in the second periopods of *Pontonides unciger* Calman (Crustacea, Decapoda, Palaemonidae). *Ohmu,* 2:87-92, fig.1.

---------- 1972. A new pontoniinid shrimp of the genus *Coralliocaris* Stimpson from Taiwan (Crustacea, Decapoda, Pontoniinae). *Ohmu,* 3 (9): 91-98, figs.1-3.

Heller, C. 1862. Beiträge zur Crustaceen-Fauna des rothen Meeres. II. *Sitzb.Akad.Wiss.Wien,* 44 (1):241-295, pls.1-3.

Holthuis, L.B. 1951. A General Revision of the Palaemonidae (Crustacea Decapoda Natantia) of the Americas. I. The Subfamilies Euryrhinchinae and Pontoniinae. *Allen Hancock Found.Publ.,Occ.Pap.,* 11: 1-332, pls.1-63.

Holthuis, L.B. 1952. The Decapoda of the Siboga Expedition. Part XI. The Palaemonidae collected by the Siboga and Snellius Expeditions, with remarks on other species. II. Subfamily Pontoniinae. *Siboga Exped.Mon.*, 39 a10: 1-252, figs.1-110, tab.1.

---------- 1953. Enumeration of the Decapod and Stomatopod Crustacea from Pacific Coral Islands. *Atoll Res.Bull.*, 24:1-66.

Johnson, D.S. 1961. A synopsis of the Decapoda Caridea and Stenopodidea of Singapore with notes on their distribution and a key to the genera of Caridea occurring in Malayan waters. *Bull.nat. Mus.Singapore*, 30:44-79, pl.1.

Kemp, S. 1922. Notes on the Crustacea Decapoda in the Indian Museum. XV. Pontoniinae. Rec.Indian Mus., 24:113-288, figs.1-105, pls.3-9.

Kubo, I. 1940. A new shrimp, *Harpilius imperialis. J.Imp.Fish.Inst., Tokyo*, 34:1-4, figs.1-3.

Miyake, S. and Fujino, T. 1968. Pontoniinid shrimps from the Palau Islands (Crustacea, Decapoda, Palaemonidae). *J.Fac.Agric. Kyushu Univ.*, 10 (3):339-341, figs.1-8.

Ortmann, A. 1890. Die Unterordnung Natantia Boas. Die Decapoden Krebse des Strassburger Museums mit besonderer Berücksichtigung der von Herrn Dr. Döderlein bei Japan und bei des Liu-Kiu Inseln gesammelten und z-Z. in *Strassburger Museum aufbewahrten Formen. I. Theil. Zool. Jb.Syst.*, 5:437-542, pls. 36-37.

Patton, W.K. 1966. Decapod crustacea commensal with Queensland branching corals. *Crustaceana*, 10 (3):271-275, figs.1-3.

---------- 1974. Community structure among the animals inhabiting the coral *Pocillopora damicornis* at Heron Island, Australia. In: *Symbiosis in the Sea*, (ed. Vernberg, W.G.). *Belle W.Baruch Library in Marine Science*, 2:2; 9-243, figs.1-2, tabs.1-4.

Stimpson, W. 1860. Prodomus descriptionis anamalium evertebratorum quae in Expeditione as Oceanum Pacificum Septentrionalum a Republica Federato missa, C. Ringgold et J. Rogers, Ducibus, Observavit et descriptit. *Proc.Acad.nat.Sci.Philad.*, 1860:22-48.

Nos. 206-207 May 1977

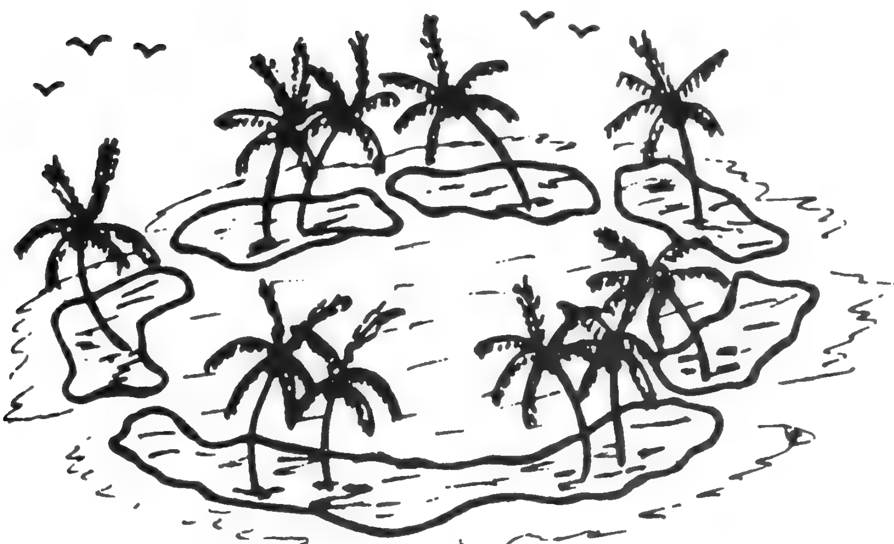
ATOLL RESEARCH BULLETIN

206. THE NATURAL HISTORY OF NECKER ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp and Eugene Kridler

207. THE NATURAL HISTORY OF NIHOA ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp, Eugene Kridler and Robert R. Fleet



Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

ATOLL RESEARCH BULLETIN
NOS. 206 - 207

206. THE NATURAL HISTORY OF NECKER ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp and Eugene Kridler

207. THE NATURAL HISTORY OF NIHOA ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp, Eugene Kridler and Robert R. Fleet

Issued by
THE SMITHSONIAN INSTITUTION
with the assistance of
The United States Fish and Wildlife Service
U.S. Department of the Interior
Washington, D. C., U.S.A.

May 1977

ACKNOWLEDGEMENT

The Atoll Research Bulletin is issued by the Smithsonian Institution as a part of its Tropical Biology Program. It is co-sponsored by the Museum of Natural History and the Smithsonian Press. The Press handles production and distribution. The editing is done by the Tropical Biology staff, Botany Department, Museum of Natural History and by D. R. Stoddart.

The Bulletin was founded and the first 117 numbers issued by the Pacific Science Board, National Academy of Sciences, with financial support from the Office of Naval Research. Its pages were largely devoted to reports resulting from the Pacific Science Board's Coral Atoll Program.

ATOLL RESEARCH BULLETIN
NO. 206

THE NATURAL HISTORY OF NECKER ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp and Eugene Kridler

Issued by
THE SMITHSONIAN INSTITUTION
with the assistance of
The United States Fish and Wildlife Service
U.S. Department of the Interior
Washington, D. C., U.S.A.

May 1977

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

THE NATURAL HISTORY OF NECKER ISLAND, NORTHWESTERN HAWAIIAN ISLANDS[1]

by Roger B. Clapp[2] and Eugene Kridler[3]

INTRODUCTION

Necker Island, now a part of the Hawaiian Islands National Wildlife Refuge, is a small, precipitous, rocky island that lies at 23°35' North, 164°42' West (Off. of Geogr., 1956: 58) near the eastern end of the northwestern Hawaiian Islands (Figure 1). Its nearest neighbors in the chain are French Frigate Shoals, lying about 75 miles to the westward, and Nihoa Island, some 155 miles to the east-south-east (Great. Brit. Hydro. Dept., 1946: 296-297).

Relatively little is known about the fauna of the island, in part perhaps due to the difficulty of making landings there. The principal previous surveys of the island were made by the Albatross Expedition in 1902, by Carl Elschner in 1914, and by the Tanager Expeditions of 1923 and 1924. The various scientific reports resulting from these expeditions, particularly those resulting from the Tanager Expeditions, and Bryan's (1942) summary of information supply most of what was previously known about the biota as well as the geology of the island.

Beginning in 1964 the Pacific Ocean Biological Survey Program (hereafter POBSP) of the Smithsonian Institution and the Bureau of Sport Fisheries and Wildlife (hereafter BSFW) began making periodic surveys of the fauna of the island. From 1964 through 1973 13 visits were made, all but five of them in the months of March and September, which together totaled only 7.0 days of observation (Table 1). Of these seven days, only three nights were spent on the island, which accounts, in part, for the paucity of data on petrels.

This report, one of a series on the northwestern Hawaiian Islands, is primarily intended as a summary of these and previous observations of

---

1/ Paper Number 75, Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D.C.

2/ Present address: National Fish and Wildlife Laboratory, Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, National Museum of Natural History, Washington, D.C. 20560.

3/ Present address: Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Kailua, Oahu, Hawaii 96734.

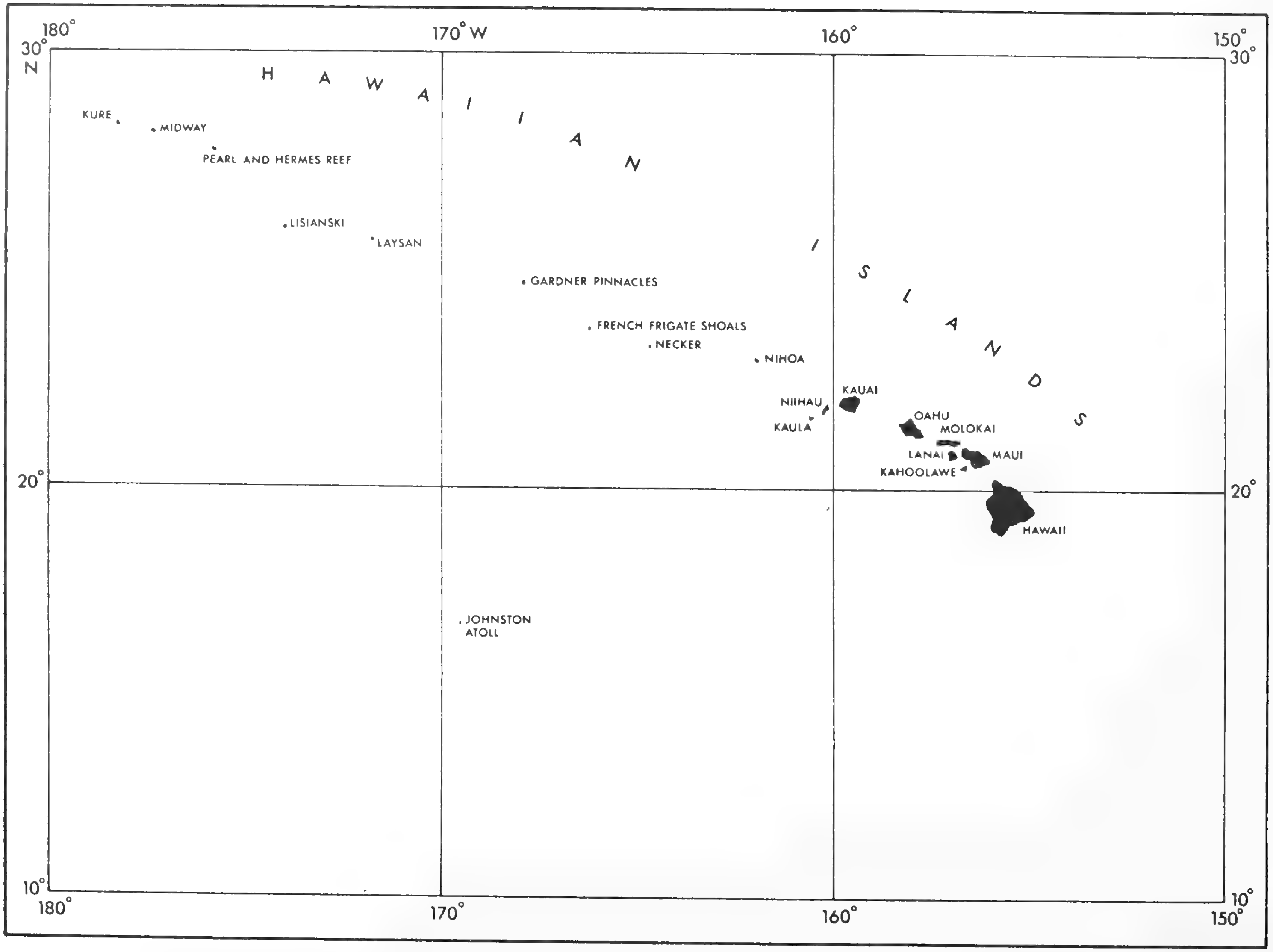


Figure 1 The Hawaiian Islands.

Table 1. Recent surveys of Necker Island by the POBSP and BSFW*

Month	Year 1964	1965	1966	1967	1968	1969	1971	1972	1973	Total Days of Observation
Mar.		BSFW POBSP (.4)		BSFW POBSP (.3)		BSFW (.4)				1.1
May						BSFW (.1)				.1
July	BSFW (.4)								BSFW (.3)	.7
Aug.					BSFW (1.4)		BSFW (.1)			1.5
Sept.	BSFW POBSP (1.4)		BSFW (1.3)	BSFW (.4)			BSFW (.3)	BSFW (.2)		3.6
Total Days of Observation	1.8	.4	1.3	.7	1.4	.5	.4	.2	.3	7.0

*POBSP is listed under BSFW when POBSP personnel accompanied BSFW field parties on one of their regular inspection trips. Figures in parentheses are the approximate number of days spent on the island. Table is complete through 1973 but does not include visits during which no landing was made.

the terrestrial vertebrates and vascular plants of the island. A brief description and history of the island are also included. Secondarily, this report should serve as a summary and reference (see Appendix Tables 1 and 2) to other biological and other information previously published about the island. Through the courtesy of Dr. Alexander Wetmore, the previously largely unreported observations on the birdlife made by him in 1923 are also included.

The present report was largely in final draft form in late 1970 and includes only slight emendation or addition after that period. Observations reported include those available through 1973. Except for botanical observations, this largely excludes the August 1968 survey, for which most data were not available.

BSFW and POBSP field notes and trip reports concerning Necker are, respectively, stored in the Bureau of Sport Fisheries and Wildlife files, Kailua, Oahu, Hawaii, and the Pacific Ocean Biological Survey Program files, National Museum of Natural History, Washington, D.C.

DESCRIPTION

Necker, with an estimated area of 41 acres (Fig. 2), is a sharply rising ridge of volcanic rock (Figs. 3 and 4) which Palmer (1927: 22) reported to be the remnant of a volcanic cone that was formerly of much greater extent. Palmer's report on the geology also gives one of the best descriptions of Necker. He reported that the island "...consists of two parts. The principal one is a ridge extending nearly due east and west, 4,000 feet long and varying from 200 to 600 feet in width. On this ridge are five peaks....The saddles between the peaks are shallow [Figs. 5 and 6], except the most westerly [between Annexation Peak and Flagpole Hill], which drops to only 76 feet in elevation [Fig. 7]. From the westernmost peak a peninsula extends 500 feet north-northeast to a gap only a few feet above sea level [Fig. 8]." Landings are generally made here and are often particularly difficult and dangerous as the prevailing winds from the northeast often cause large breakers to break across this gap. "The lesser part of Necker Island, Northwest Cape [Fig. 9], extends about 800 feet northeast from this gap....At the east end of the main part of Necker is a low islet about 75 feet wide and 200 feet long. It is awash at high water and waves break over it continually."

On the north side of the islands the rocks rise precipitously to the peaks but on the north side are somewhat less steep and according to Emory (1928: 51) "are easily climbed."

The steep slopes of the island have little or no vegetation and are craggy and wave-sculpted where alternating layers of harder and more soft rock have been differentially eroded and bird droppings often whiten the face of the rock (see Fig. 9). Along the shallow valleys and on the rounded crests of the hills a few species of plants are well established in the thin soil (see Vegetation Section).

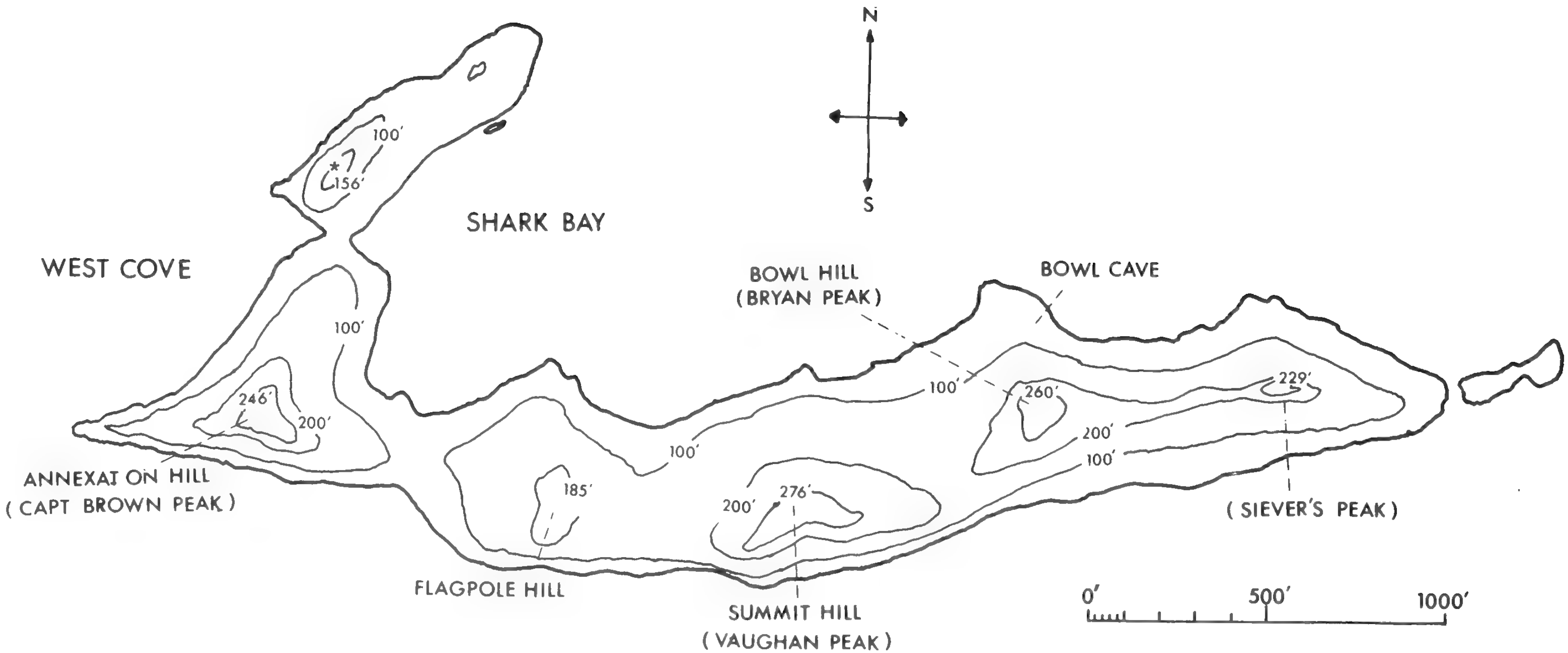


Figure 2 Map of Necker Island. After Judd (in Palmer, 1927) and Elschner (1915). Names in brackets are those used by Elschner; the others are those used by the Tanager Expedition and subsequent visitors.

Figure 3   Aerial photograph of Necker Island showing prominent features of island. Official U.S. Navy photograph, January 1966.

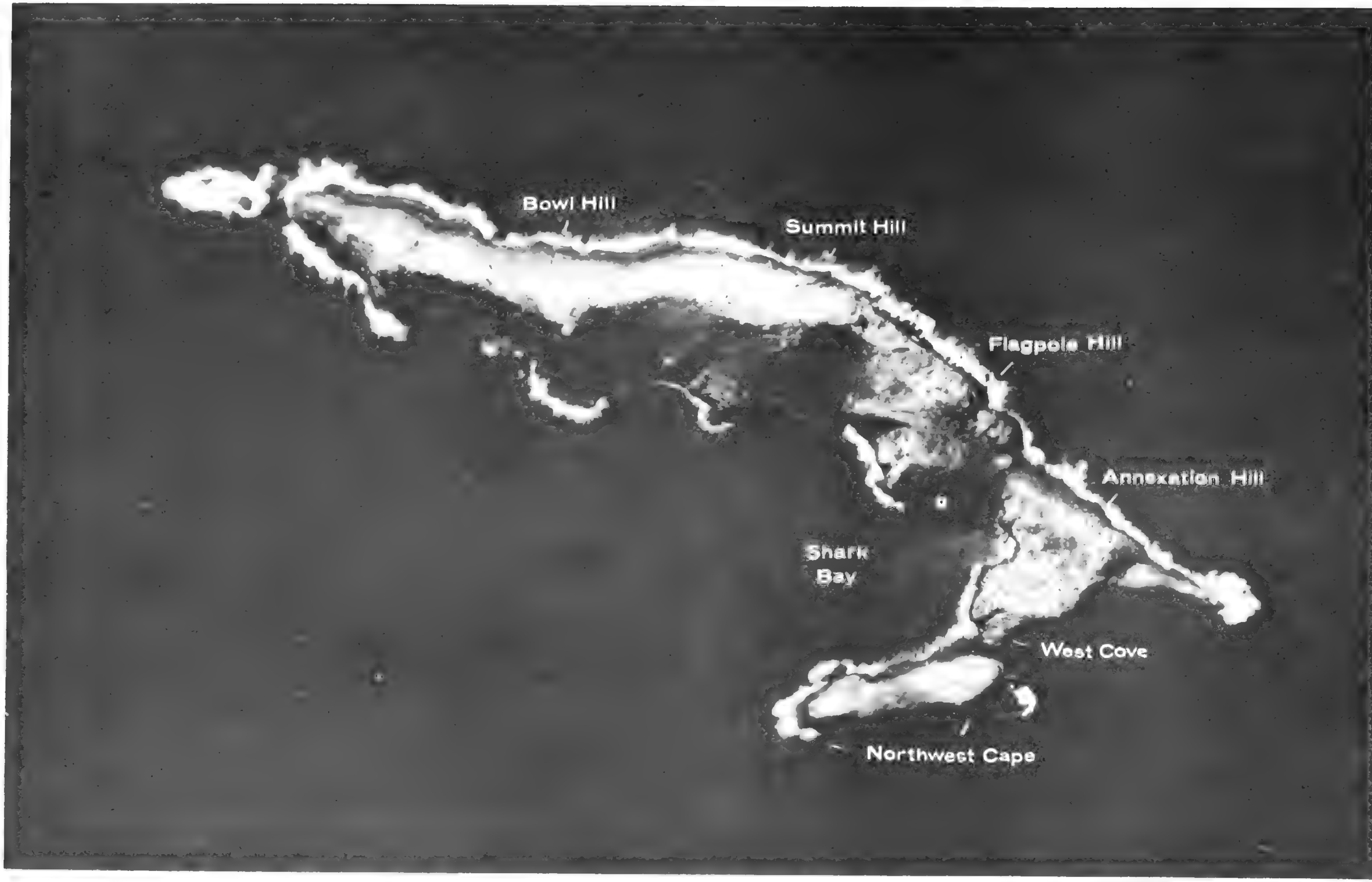


Figure 4 Oblique aerial view of Necker Island from the northeast. BSFW photograph by David B. Marshall, June 1962.

Figure 5 Shallow ridge between Flagpole (right) and Summit (left) Hills. Photograph by Derral Herbst, 28 August 1968.

Figure 6 Shallow ridge between Bowl (middle) and Summit (right) Hills. Photograph by Derral Herbst, 28 August 1968.

Figure 7 Low gap between Flagpole (left) and Annexation (right) Hills. Photograph by Derral Herbst, 28 August 1968.

Figure 8 Gap between Northwest Cape and Annexation Hill as viewed from Bowl Hill. Shark Bat in right mid-ground and looking into the East Cove landing. Photograph by Derral Herbst, 28 August 1968.

231-338 O - 77 - 2

Figure 9 Frequently used landing area in the West Cove looking at the Southeastern Peak of Northwest Cape. Photograph by Derral Herbst, 28 August 1968.

GEOLOGY

Palmer (1927) is the only one who has written to any extent on the geology of Necker and our brief account here is largely taken from that paper. Although the remnant of a volcanic cone, no part of the original surface remains, all the present surfaces having resulted from the action of wind, sea, and running water. Palmer suggested that the deeper valley between Annexation and Flagpole Hills has resulted from greater wind erosion caused there by the funneling of the northwest trade winds by the main ridge of the island and by Northwest Cape. He (*op. cit.:* 23) considered it likely that

> at least a few hundred feet of overburden rocks have been removed from all parts of the island. There are now exposed at the surface various dikes and sills, some of which are entirely free of gas pores. This feature is usually taken to mean that the lava cooled and solidified under considerable pressure, which in turn implies a considerable overburden.

Necker has no definite stream channels and all rainwater either sinks into the rocks or runs off through unorganized channels. During his visit Palmer found two seeps of ground water, both evidently much contaminated by bird droppings. One was found near Bowl Cave (see Fig. 2) on the north slope of the island; the other was about 30 feet above sea level on the north side of the saddle between Flagpole and Annexation Hills.

Palmer also noted that the beds of lava composing the island are in general four to six feet thick and that they extend laterally for considerable distances. Two unusually thick beds, 15 to 20 feet thick, are to be found at the east end of the main island. He noted that in general the lava beds strike "N. 70° W., and dip 10° NE" and that the lava beds are

> cut by a number of nearly vertical dikes that strike about N. 70° E....The dikes vary from one to four feet in thickness. Some of them, notably the one on the northeast face of [Annexation Hill]...are dense and nearly free of vesicles, but others are moderately porous. Most of the dikes are fine grained at the margins and coarse grained in the interior. Some of the dikes branch one or more times, and one pair of dikes [is] connected by an oblique dike running about east-west. The dike on the southeast side of Northwest Cape connects with and seems to have fed a sill that outcrops on both sides of the cape. This sill meets the shore near the middle of the cape and extends upward toward the southeast end of the cape, cutting

> across several flows in one place. A sill about two feet thick crops out for about 150 feet on the summit of the main island near its east end, and was also presumably fed by the dike which is continuous with it.

Palmer concluded that the vent of the volcanic cone of which Necker is a remnant lay to the southwest of the present position of the island. He remarked, however, that his conclusion (1927: 24) "disagrees with the fact that Necker lies to the southwest of the axis of the ellipse outlined by the surrounding shoals," but suggested that this might be explained by the fact that the shoal "was composed of two or more volcanic cones....and that the windward cones have been removed as they were most exposed to attack by waves driven by the prevailing northeast trade winds. The area of the shoal around Necker is about 650 square miles which is large enough to have included two volcanic domes."

Palmer found no evidence of faulting in the beds composing Necker and noted that the beds along the westernmost saddle are continuous.

Analyses of the rock composition have been given by Palmer, Möhle (1902), Powers (1920) and Washington and Keyes (1926). All the rocks studied were basalts and within this classification consisted of four types, andesine, olivine-labrodorite, picrite and nephalitic basalts. Further details of chemical composition of these rocks can be found by consulting the literature cited.

Palmer also found gypsum stalactites and stalagmites in some of the shallow caves of the island. These differed from the usual in that they had fairly good crystal outlines rather than being more rounded in form. According to Palmer, these probably resulted from the evaporation of salt spray.

HISTORY

Prehistoric Habitation

Evidence of prehistoric habitation of Necker Island was noted during one of the earliest landings on Necker which occurred about 1879. Captain William C. Bruhn, then a young sailor, evidently on the schooner JULIA, landed and explored the island.[1] When he was interviewed by Atkinson many years later Bruhn remembered seeing marae (stone platforms with a conventional arrangement of uprights), four or five idols, a few stone adzes, and a stone "shaped like a rough dumbbell, two rough ends with a handle to clutch with the hand. The Hawaiians said that when sharks were led to shallow

---

[1] Emory (1928: 55) found no evidence of a visit in 1879 but discovered that the JULIA had sailed to the South Pacific on 13 July 1882.

places that this dumbbell was used to kill them by beating them on the head." None of the idols was collected because of the superstitious fear of the Hawaiians on Bruhn's ship, but the dumbbell-shaped stone was taken and later transported to San Francisco (Emory, 1928: 54).

The presence of idols and images was again noted on 27 May 1894 when the island was annexed by the Hawaiian government. Seven idols were taken to Honolulu and a photograph of six of them was published in the Journal of the Polynesian Society (Alexander, 1894: 153).

Subsequent visits and collections are listed in detail by Emory (1928). Four images (two now in the British Museum) were collected by a party from the HBMS CHAMPION on 24 September 1894, but no idols were found on seven subsequent visits. The latter visits included one on 12 July 1895 by King, two of unknown date by George N. Wilcox, visits in 1910 and 1913 by personnel from the Revenue Cutter THETIS, and two visits by H.L. Tucker and party in 1917. Photographs were taken of several marae on the latter visit.

On 6 October 1919 Gerrit P. Wilder collected an image leg and a re-shaped image. In the summer of 1923 a number of artifacts (including a hammerstone, grindstones, adzes, a chisel, an awl and bowls) and skeletal material were found by members of the Tanager Expedition.

Observations made during the Tanager Expedition and on earlier visits were reported in great detail by Emory (1928) and need not be repeated at length here. Some records, however, are worth noting.

Emory reported finding 33 marae. Most were rectangular structures with a narrow elevated platform usually found at the rear, and a lower broader terrace at the front (see Fig. 25 in Emory, 1928: 60). Various stones standing upright were placed on the structure (Figs. 10 and 11). These platforms ranged in length from 17.5 to 64 feet. The length in 16 of these averaged about 25 feet, and in 11 about 40 feet. In 25 maraes the width of the platform was four to six feet, in two, three feet, and in three, eight to nine feet.

Emory also counted 25 terraces that were rectangular, unpaved, low, and usually narrow. Two were just west of the summit of Annexation Hill and a group of eight was south of Flagpole Hill. Another group of six terraces was found between Flagpole and Summit Hills, and seven were found just northwest of the crest of Summit Hill where a double terrace also was discovered.

Despite a considerable search for areas where people might have lived, only eight hollows were found in the bluffs of Necker that gave evidence of occupancy. Emory reported that all eight grottos could probably shelter no more than 24 persons. Only Bowl Cave, where most artifacts were found, had evidently been continuously occupied.

Figure 10   Adult and immature Red-footed Boobies and Great Frigatebird roosting on uprights of marae on Annexation Hill. Blue-faced Booby in mid-ground and large nestling Great Frigatebirds in background. Photograph by Derral Herbst, 28 August 1968.

Figure 11   Immature Red-footed Boobies roosting on uprights of marae on Annexation Hill. Nestling Great Frigatebirds and immature Red-footed Booby in foreground.

There human leg bones were found on the floor. Emory speculates that the bones may have been taken to the cave for use in making fish hooks, a common practice among Hawaiians.

Emory gives detailed descriptions of all images available to him and stated that all were "male human figures carved in the conventionalized form." The images, carved from vesicular basalt, varied in color from light to dark gray, and ranged in height from eight to 18 inches. They weighed from four to 25 pounds, "inclining equally to extremes."

After making a detailed comparison of the archaeology of Necker and nearby Nihoa, and of their cultures in comparison with other Pacific cultures, Emory concluded that

> this review of the cultural affinities of Nihoa and Necker, reveals the Necker culture as one which had been introduced to the Hawaiian Islands from southeast Polynesia, probably from Tahiti, and which, on the islands excepting Necker had become for the most part displaced, and for the rest, modified by the historic Hawaiian culture.

He ended by saying "it seems reasonable to adopt the view that the Necker culture is a pure sample of the culture prevailing in Hawaii before the thirteenth century...."

About 15 years after the publication of Emory's paper, charcoal and wood found in 1923 in Bowl Cave were carbon dated by Libby (1954: 742). The age of the charcoal was placed at 166 to 200 years and that of the wood at 0 to 250 years. Although the material was possibly contaminated, the results suggest a fairly recent occupation of Necker, but clearly do not rule out the possibility that the structures themselves were erected six or seven centuries ago. Certainly the charcoal and wood could have been brought to the island at a later date by fishermen or wandering natives.

European Discovery and Early Visits

All authors agree that the first European to discover Necker was the French navigator, Jean François de Galaup, Comte de la Pérouse. On 4 November 1786, en route to Macao, la Pérouse's frigate, the BOUSSOLE, and its companion the ASTROLABE sighted a small rocky island (Buck, 1953: 54). The vessels stood offshore all night. The following morning La Pérouse (1799) made the following notations:

> This very small island is little more than a rock of about five hundred toises [= 1,000 yards] in length, and sixty [= 120 yards] in elevation at the most.

> It does not exhibit a single tree, but there is a great deal of grass near the summit. The naked rock is covered with the dung of birds, and its white appearance affords contrast to various red spots, upon which the grass has not sprung up. I approached within the distance of a third of a league. The banks were perpendicular, like a wall, and the sea broke so violently against them, that it was impossible to land. As we sailed almost entirely around it, the plan of this island, as well as the different views, are perfectly accurate. Its latitude and longitude, as determined by Mr. Dagelet, are 23°34' north, and 166°52' west of Paris.[2] I called it Isle Necker [in honor of Monsieur Jacques Necker, French Minister of Finance under Louis XVI].

The exact date of the first historic landing on Necker is not precisely known but apparently occurred at the beginning of the 19th century. Bryan (1938: 22) reported that John Turnbull, who visited Hawaii December 1802 to January 1803 in the British ship MARGARET, learned that two Hawaiians had landed on Necker sometime previously and had noted a "range of stones, placed with some regularity in the manner of a wall, and about three feet high."

Necker was sighted at least four times in the mid-1800's but no landings were made. The PORPOISE and the OREGON, part of the U.S. Exploring Expedition, passed offshore on 1 December 1841. Charles Wilkes (1845: 389-390), commander of the expedition, remarked that "birds, especially the white tern, had been seen in numbers prior to [sighting the island]..." The vessels, three miles off the reef surrounding Necker, made soundings but did not attempt to land because of a "furious surf beating on all sides of the island." Necker's position was calculated as 164°37'00" W., 23°44' N.

Necker was again observed from offshore on 24 April 1857 by Captain John Paty of the schooner MANUOKAWAI. Paty (1857: 40) described Necker as "a precipitous rock, 300 feet high, 1 mile long and half a mile broad, with small patches of grass on its surface."

Two years later, on the morning of 1 January 1859, Lt. John M. Brooke (ms.) viewed the island from the U.S. schooner FENIMORE COOPER. Later that year, on 29 April, Captain N.C. Brooks of the GAMBIA sighted Necker and took its position. Of the island itself Brooks (1860: 499) remarked only that, "it is rocky, and about 1-1/2 to 2 miles long...."

---

[2] The Greenwich longitude would be 164° 32'.

In 1886 the fishing schooner GENERAL SIEGEL fished off Necker (Farrell, 1928: 253). This trip is notable in that this was the first time seals were recorded for the island.

On 28 May 1891 the island was viewed from the KAALOKAI by Henry Palmer and George C. Munro, members of the Rothschild Expedition which was collecting bird specimens in the northwestern Hawaiian Islands. Although the party wished to land, it was prevented from doing so by heavy seas (Rothschild, 1893-1900: viii).

Hawaiian Annexation

The historical details of this period were carefully researched and analyzed by Pauline N. King (ms.). Our account follows hers closely, and we are deeply indebted to her. Her thesis should be consulted for further details and for citations of unpublished correspondence and official communications.

In the 1890's Necker became an island of international interest since it was not clear which if any nation held title to it. Great Britain was interested in laying claims to islands which would serve as mid-ocean stations for a cable connecting Canada and the Austral-Asian colonies. She already claimed Fanning in the Line Islands and she possessed many islands between the Lines and Australia which would serve adequately as stations. However, she needed an intermediate station between Canada and Fanning and the only possibility lay within the Hawaiian group.

In the fall of 1893 two Canadians, Mackenzie Bowell and Sanford Fleming, began inquiring into the feasibility of a cable station in the main Hawaiian Islands, and into the physical characteristics and international status of Necker. They concluded that the main Hawaiians would be unsuitable, partly because they felt that national pride demanded national ownership of an island station, and partly because they felt uncertain of the political future of the Hawaiian government. Fleming strongly recommended that Necker Island be secured as a British possession.

Some months of political maneuvering followed. During this period, British officialdom attempted to discover whether the Hawaiian government did, in fact, claim Necker, and, if not, whether the United States might object to Britain making such a claim. The United States government remained neutral and noncommittal on the matter, only indicating that it considered trans-Pacific telegraphic communication to be of benefit to the United States as well as to Great Britain and her colonies. The Hawaiian government was initially open to the idea but wanted to know more details about the British plan. Hawaii wished to do nothing detrimental to the interests of the United States.

On 24 May 1894 the presence in Honolulu of the CHAMPION, a British warship, and the visit of inquiry to the survey office of

the Hawaiian government by the acting British Vice-Consul, led to the rumor that the British were en route to claim Necker Island. As a result the Executive Council of the Hawaiian government decided that Captain James A. King, Minister of the Interior, should travel to Necker immediately and claim it for Hawaii. On 25 May King's ship, the chartered interisland steamer IWALANI, departed from Honolulu at 1710. The CHAMPION departed 50 minutes later. Many observers interpreted this as a race to claim Necker Island, a race that the CHAMPION would probably win since it was the faster ship. Subsequent events indicated, however, that the CHAMPION was on no such mission.

On 27 May the IWALANI reached Necker, and King, accompanied by members of the crew, went ashore to claim the island.

A quotation from the log of Captain Freeman (Emory, 1928: 55) describes the landing:

> At 11:00 AM arrived at the island and dropped anchor in 18 fathoms of water. We lowered a boat and proceeded to land at once with His Excellency, Capt. J.A. King, Capt. Freeman, C.B. Norton and nine sailors, leaving the vessel in charge of the second officer. After considerable difficulty the party was safely landed. A hard climb up a rugged cliff 260 feet high, was successfully accomplished, when His Excellency Capt. King hoisted the Hawaiian flag, read the Proclamation and took possession of the island in the name of the Hawaiian Government....after a stay of about four hours on the island, we left at 5:30 PM for home, steering E. by S., arriving at Honolulu on Tuesday evening [May 29].

While on the island, the party erected a flagpole and attached to it, within a copper tube, a copy of the paper claiming annexation. Tucker (ms.) reports the contents of this paper:

> I, James A. King, Minister of the Interior of the Provisional Government of the Hawaiian Islands, in pursuance of a commission granted to me by His Excellency, Sanford B. Dole, President of the provisional government of the Hawaiian Islands, do hereby in the name of said government take possession of this island, known as Necker Island as a part of the Hawaiian Territory; the same being within the Hawaiian archipelago in Lat. 23°35'18" North and Long. 164°39'00" west, and having been claimed by the Hawaiian territory since

> the year 1845 when an expedition[3] under Capt. W.M. Paty was sent to survey said island.
>
> Done at Necker Island the 27th day of May in the year of our Lord 1894.
>
> Signed: J.A. King, Minister of the Interior
> Wm. Freeman, Master of Hawaiian Str. Iwalani
> Jas. Gregory, Chief Officer "Iwalani"
> Albert Tullott, 2nd " "

Late 19th Century Visits

On 24 September 1894, the HBMS CHAMPION did pay a visit to Necker and landed a survey party. At least six men went ashore, but Captain Rooke was apparently not among them. Although the Hawaiian government had asked that no images or artifacts be disturbed, four were collected.

The British had not yet abandoned their intention of using Necker Island for a cable station. The British government sent a mission to Honolulu to engage in negotiations with the Hawaiian government but they did not achieve their aims. They failed in part, perhaps, because of anti-British sentiment in the Hawaiian Islands, and in part because of the unwillingness of the Hawaiian government to jeopardize possible ties with the United States.

Necker was again visited 12 July 1895 by Captain J.A. King (ms.) and a survey party on the ship LEHUA. While mapping the island, they

> landed and found that the flagpole...placed in position in May, 1894, had blown down. We replaced the staff in position. We found the Copper Cylinder which had contained the Proclamation open and the document on a rock under the staff. The Proclamation had been opened and a written memorandum in pencil was on the back of it, signed by Officers of the H.B.M.S. Champion. One name I was able to decifer as that of Lieut. Nugent, the others I could not make out. The memorandum stated as near as I can remember as follows: 'We, the undersigned officers of the H.B.M.S. Champion, on 24th of September 1894, surveyed Necker Island shoal; running S.E. 35 miles, N.E. 15 miles, and ten miles in all directions. We found no less than 15 fathoms of water one mile distance from shore.'

---

[3] We have been unable to discover any other reference to this 1845 voyage.

> We returned the Proclamation to the Cylinder and made it fast to the base of the staff.

Tucker (ms.) in 1917 also saw this Proclamation and reported the text as "this island known as Necker Island was surveyed by the undermentioned officers of Her Hawaiian Majesty's ship Champion Sept. 1894 and also the bank extending 35 miles SE, 15 miles NE, ? miles in the other direction." The "Hawaiian Majesty's" part of this quotation is undoubtedly incorrect but the absence of a date for September 1894 throws some doubt on exactly when the island was visited. Tucker also deciphered a number of other names indicating that Lieut. Rowland Nugent, Lieut. Frederick, A.H. Walker, Richard Markham and three others including two midshipmen had visited the island.

George N. Wilcox evidently visited the island on at least two occasions at about this period (Emory, 1928: 48), but we have no information concerning his visits.

1900-1929

In 1902 Necker was visited by the U.S. Fish Commission Steamer ALBATROSS which was engaged in deep-sea investigations around the Hawaiian Islands. The ship arrived offshore on the afternoon of 30 May and anchored off the west end of the island. The following day the four naturalists aboard (Charles H. Gilbert, Walter K. Fisher, John O. Snyder, and Charles C. Nutting) landed and spent a few hours on the island (Thomas, ms.). Fisher later reported that 17 species of birds were seen and described one of them (Blue-gray Noddy) as a new species (Fisher, 1903a, b).

In response to considerable agitation over Japanese feather gathering in the northwestern Hawaiian Islands in the early 1900's, Necker was included in the Hawaiian Island Reservation. This reservation, established 3 February 1909 by President Theodore Roosevelt's Executive Order No. 1019, included all northwestern Hawaiian Islands but Midway. They were placed under the jurisdiction of the Department of Agriculture and set aside as a preserve for the native birds.

From 1909 to 1916 the U.S. Coast Guard Cutter THETIS voyaged frequently along the northwestern Hawaiian Chain. The visits had several objectives: apprehension of Japanese bird poachers who had been destroying birds on various islands; inspection of the islands to determine whether further poaching had occurred; transportation of various scientific parties who wished to study the fauna of the islands; and transportation of mail and supplies to Midway Atoll. Parties attempted to land on Necker on several occasions.

As the THETIS passed Necker on the morning of 13 January 1910, W. Jacobs, the vessel's commander, noted an absence of bird and human life on the island which was "covered with a growth of grass

on the central ridge." No landing was made because of dangerous surf (Jacobs, ms.). The THETIS visited Necker again on 22 May, 25 August, and 5 September but no evidence of molestation of the birdlife was seen.

In 1912, while transporting a U.S. Biological Survey party to Laysan, the THETIS passed offshore on 18 December. Heavy swells prevented landing. On 9 March 1913, during the return trip of the survey party, two of its members, George Willett and Alfred M. Bailey, attempted to land in a ship's boat but were again prevented from doing so by high surf. Willett, undaunted, swam ashore. Despite the inconvenience of being naked, Willett spent about two hours on the island and obtained a few notes on the kinds of birds present and their nesting status (Bailey, 1956: 32; Willett, ms.).

On 8 September 1914 Carl Elschner and others went ashore from the THETIS. Elschner (1915) made notes on minerals and geology and named a number of the prominent features of the island (see Fig. 2). Apparently these names were never in common usage and all were replaced by names subsequently applied to them by the Tanager Expedition.

In November 1914 W.A. Bryan (ms.), a noted ornithologist and sometime Honolulu politician, made application to H.W. Henshaw of the Biological Survey for the lease of Necker Island. His reasons for so doing were that "the longing to be 'monarch of all I survey' has always been with me and a lease to Necker seems to be about as near as I am liable to get to realization of the longing." Despite Bryan's longing the lease was never granted.

Bryan was not the only one to attempt to lease Necker. The Territory of Hawaii leased Necker to A.C. Lovekin on 2 June 1907 (Frear, ms.).

The THETIS again passed Necker on 19 March 1915 but once more heavy surf made a landing impossible.

In early 1916 the THETIS paid two visits to Necker and on both visits men landed on the island. On the first visit, late in the afternoon of 27 January, three officers landed by swimming to a shelf of rock in the East Cove (now known as Shark Bay). During their brief visit they explored only the westernmost peak of the island (Annexation Peak). An easier landing was effected on 11 February when slight swells allowed the survey party to step from the dinghy to a rock shelf edging Shark Bay. During the three hour visit most of the eastern portion of the island was explored. Lt. W.H. Munter, who visited the island on both occasions, later made a detailed report of this visit and included a considerable amount of information on the birdlife (Munter, ms.).

Necker was visited twice in 1917. H.L. Tucker and others landed from the power sampan NAKAIWA on 25 October, and Tucker and seven other members of the crew of the J.A. CUMMINS stopped there on

5 November (Tucker, ms.). They rediscovered the Annexation Documents and noted the few birds present. Tucker and Eben P. Low took a number of photographs of the birds.

The following fall, on 3 September 1918, the USS HERMES steamed around the island during an inspection trip of the northwestern Hawaiian Islands. In a report of this trip Diggs (ms.) briefly noted the presence of six species of birds. On 6 October 1919, Wilder, Warden of the Hawaiian Islands Bird Reservation, visited Necker in the lighthouse tender KUKUI (Emory, 1928: 59).

The visits made to Necker by the Tanager Expedition in June 1923 and in July 1924 resulted in a greater accumulation of knowledge about the island than did any previous or subsequent visit. Plans for this expedition, which visited all the northwestern Hawaiian Islands, Wake Island, and Johnston Atoll, were formulated in 1922 in conferences between the U.S. Navy National Research Council, the U.S. Biological Survey, and the Bernice P. Bishop Museum. The Navy provided the ship (the minesweeper TANAGER), a director of naval work (Commander S.W. King), and agreed to chart hydrographic data; the Biological Survey provided an ornithologist (Alexander Wetmore) to lead the party, a rabbit-killing specialist (E.C. Reno), and a movie camera. Other personnel were supplied by the Bishop Museum (Gregory, 1924: 19-22).

We are not certain of the exact itineraries of every individual but believe the following account, derived primarily from an examination of Wetmore's (ms.) field notes, is accurate.

In all, five voyages were made which included three visits to Necker (two on trip C and one on trip E). On trip C, while part of the field party remained on Nihoa, others including Anderson, Atkinson, Judd, Palmer, Caum, and Cartright, proceeded to Necker where they set up camp on 12 June. On the 16th Judd, Palmer, Caum, and Cartright departed for Nihoa where they replaced Wetmore, Schlemmer, Grant, Bryan, and Thaanum who sailed to Necker where they remained from the afternoon of 17 June through the morning of 21 June. Atkinson departed Necker on the afternoon of 17 June. After a survey of French Frigate Shoals, part of that field party returned to Necker for a day's survey on 29 June. Those going ashore included Wetmore, Judd, Cartright, Anderson, Caum, Palmer, Bryan, and Schlemmer.

The following year, at the request of the National Research Council, the Navy provided the TANAGER for a resurvey of Necker and Nihoa. This survey placed most emphasis on archaeological work. The field party (Appendix Table 1) camped on Necker from the morning of 15 July until the afternoon of 18 July (Gregory, 1925: 19-20).

1930-1959

There are few records of landings on Necker during this period. The island was often sighted in the 1930's and '40's by U.S. naval vessels engaged in various fleet maneuvers (Amerson, ms.) or by U.S. Coast Guard vessels cruising up the chain.

On 4 March 1936 a landing was made by A.D. Trempe (ms.), cooperator for the Biological Survey, and members of the crew of the Coast Guard vessel RELIANCE, B.L. Bassham commanding. Trempe later wrote a brief report on birds seen on other islands visited (Nihoa, French Frigate Shoals, Laysan) during the cruise but for Necker reported only that "much the same birds" were seen as were seen on Nihoa.

The name of the Hawaiian Island Reservation was changed on 25 July 1940 to the Hawaiian Islands National Wildlife Refuge, and its jurisdiction was transferred to the U.S. Fish and Wildlife Service in the U.S. Department of the Interior. In December 1951 the Wildlife Service entered into an agreement with the Territory of Hawaii; one of the provisions of the agreement was that patrol of the refuge would be by Territorial personnel.

On 20 December 1953 Frank Richardson of the University of Washington visited Necker briefly from the Coast Guard vessel BUTTONWOOD. He covered only about half the island but recorded 12 species of birds (Richardson, pers. comm.). Some of his observations were later incorporated in a paper on the breeding cycles of Hawaiian seabirds (Richardson, 1957).

Dale W. Rice and Karl W. Kenyon made an aerial survey of the island on 28 December 1957. Albatross populations were estimated from counts in low-level photographs (Rice and Kenyon, 1962).

1960-1969

In 1961 Necker was visited 25 to 26 March by the USS DUVAL COUNTY (LST 758) which was determining exact locations of the northwestern Hawaiian Islands. During this visit the project known as HIRAN I was plotting first order astronomic strata and azimuth marks by conventional methods (Roach, ms.).

On 11 June of the following year Necker was visited from the USS STONE COUNTY by four biologists, two of them from the Hawaii Division of Fish and Game (Appendix Table 1). During their very brief visit a few notes were made on vegetation, birds, and the debris left from the HIRAN I operation (Kramer and Beardsley, ms.). At that time several military personnel were camping on the island and were engaged in the HIRAN II project (Marshall, ms.).

Responsibility for patrol and inspection of Necker was assumed in March 1964 by the U.S. Bureau of Sport Fisheries and Wildlife in

the U.S. Fish and Wildlife Service and a refuge manager was assigned to Hawaii. From then through July 1973 13 landings were made on Necker (see Table 1). Personnel from the Smithsonian Institution's POBSP participated in four of the surveys, those made in March and September 1964, March 1965, and March 1967.

Landings on this island have been exceedingly hazardous and inclement weather has often prevented landings or, in some instances, caused precipitate departures. Some idea of the difficulty and hazards of landing on Necker can be gotten from two recent first-hand accounts.

Concerning the departure on 22 March 1969, John Sincock noted that

> Viewing a 25 foot surge at the rock shelf [from which departures are made] and frequent 3-4-foot-deep waves crashing across [it] I suddenly agreed wholeheartedly with [the] recent memorandum... that hazardous duty pay was justified....[Eugene] Kridler, [David] Olsen and I had our share of being knocked off our feet, swept along the rock ledge, and then being swept toward the edge when the sea dropped 20-25 feet. Kridler's extended hand prevented me from going over once, and I think I reciprocated 2 or 3 waves later. We...lost track of how many times we were knocked down, or which way was up. Olsen jumped to the [rubber] boat in good shape and was taken to the life boat. Two knockdowns later the rubber boat returned for Gene and me...we both had decided a free dive into the rubber boat was preferable to another sluicing across the rocks. We waved off the bowline... because of the hazard of becoming entangled. I jumped into space like a skydiver and felt like I had forgotten my parachute, but I didn't catch up with the boat until it was at the bottom of the surge. Kridler...dove next, [and landed] spread-eagle on top of the coast guardsman in the bow.... Only one or two bags of equipment were lost and wounds were only superficial (BSFW).

On the next visit, 30 May 1969, Olsen described the perils of landing on Necker. Since the usual landing place (the northwest side of the low rock shelf connecting the main island and Northwest Cape) had proven hazardous on previous visits, an alternative landing place on Shark Bay was investigated and Olsen decided to swim ashore. His account of the attempt points out another of the hazards around the island.

> I was about 75 ft. from the shoreline when six sharks came rushing at me from my left front.

> I turned to face them as they went behind me --another 10 sharks came in from my right. The water was simply infested with sharks swimming round and round me in a...[frenzied] ...manner. Some were no more than a foot from me as they sped by me. At that time I was about 25 ft. from the ledge and I swam like I never had before, expecting to be attacked at any second. Fins [were] all around me on the surface, and the water was literally boiling with sharks...Finally, a wave swept me up on the ledge, but I was unable to hold on and I was washed into the surge again--[into a] mass of swirling fins. I caught the next swell and scampered to safety. As I stood there I counted 45 sharks swimming around in the waters at my feet (BSFW).

The primary purpose of most of these recent surveys has been inspection and patrol of the island. No survey has been longer than two days. Nonetheless, a considerable amount of information on the biota has been obtained and these data are the primary basis for the accounts of the wildlife that are presented in the following sections of the report. Itineraries, personnel, and a summary of the results of the surveys are presented in Appendix Tables 1, 2, and 3.

In February 1967 Necker was designated a natural area within the refuge system. This designation stipulates that the island's ecology is to be kept as free as possible from outside influence and disturbance. The island is dedicated to research. Visiting is limited solely to scientists on approved research programs and entry is only by permit from the Bureau of Sport Fisheries and Wildlife.

VEGETATION
by Derral Herbst

Although numerous parties have stopped at Necker, visits were brief and few botanical collections were made. La Pérouse (1799), who was the first to mention the vegetation of the island, stated that in 1786 "It [did] not exhibit a single tree, but there [was] a great deal of grass near the summit." Both Captain John Paty (1857: 40) and the annexation party who visited Necker in 1857 and 1894 respectively also noted patches of grass (Anon., 1894). Fisher (1903a: 777) of the Albatross Expedition gave a slightly more detailed description of the vegetation:

> The wider shelves of the island are sparsely covered with a flesh-stemmed, yellow-flowered portulaca (*Portulaca lutea*), and the summit is rather plentifully grown over with *Chenopodium*

> *sandwicheum* bushes, on which large colonies of *Sula piscator* [= *S. sula*, Red-footed Booby] and *Fregata aquila* [= *F. minor*, Great Frigate-bird] were nesting at the time of our visit.

Elschner (1915: 16) briefly mentions the vegetation as being "slight...and this...[is found] in higher, more flat parts of the island while the lower parts of the vertical walls and the shore rocks are bare." While he alludes to plant collections made--"my time being limited I was unable to gather many plants on this island"--the disposition of the specimens is unknown.

The first compenhensive botanical collections were made by the Tanager Expedition in 1923 and 1924. The resulting publication on the vascular flora (Christophersen and Caum, 1931) concurs with all earlier observations in that the vegetation of Necker is described as sparse and inconspicuous. During the 1923 Tanager survey, C.S. Judd, a forester, sowed seed of seven species of plants in the saddle between Flagpole and Summit Hills (Christophersen and Caum, 1931: 7; cf. annotated list below). None of these plants was found growing there subsequently.

Recent collections and observations were made by D. Herbst (ms.) (UH), E. Kridler (BSFW), and C.R. Long (POBSP).

In comparing past accounts of the vegetation, it appears that the composition has remained fairly constant over the years. Probably, differences can be attributed to the amount of rainfall prior to the visit. The vegetation cover was sparse on recent visits. Plants were restricted primarily to the top of the island, with some intermittently distributed on the natural terraces lower on the side.

Vascular plants have been collected on Necker by the following: J.O. Snyder, May 1902; E.L. Caum, June 1923; E. Christophersen, July 1924; E. Kridler, July 1964; and C.R. Long and J.W. Beardsley, September 1964. Specimens are deposited in the B.P. Bishop Museum Herbarium (BPBM), the Herbarium of the University of Hawaii (UH), or the U.S. National Herbarium of the National Museum of Natural History (USNM).

The following list notes all 13 species of vascular plants collected from, introduced to, or observed on Necker Island. Three of the five species now growing there, *Panicum torridum*, *Chenopodium oahuense*, and *Sesbania tomentosa*, are endemic to Hawaii, while the other two, *Sesuvium portulacastrum* and *Portulaca lutea*, are wide-spread throughout the Pacific islands. A list of lichens (eight species) from this island may be found in Magnussen (1942); Tsuda (1966) lists 17 species of marine algae.

Gramineae

Panicum torridum Gaud.

Caum 56 (BPBM), Christophersen 10 (BPBM), Kridler 3 (UH), Long 2445, 2450, 2455 (BPBM).

As would be expected, the amount and distribution of this annual grass have varied more than those of the other four phanerogams. Christophersen and Caum (1931: 7) report that it was fairly common on the north side of the main island in 1923, but one year later only two clumps were seen. In June 1962 (Kramer and Beardsley, ms.) small tufts were found everywhere on the island's crest, while in August 1968 the grass was found in moderate numbers only, and these primarily on Bowl Hill. This grass was also thought to be most abundant in the vicinity of Bowl Hill in September 1964 and 1966 (BSFW). The short growing period, the rapid wearing of dead tufts by the seabirds and the ease by which the wind can disperse the densely vestured spikelets can explain the varied distribution patterns.

Palmae

Livistonia australis Martius
Pritchardia pacifica Wendl.
Pritchardia sp.

Seeds of all three sowed in 1923; not found subsequently.

Casuarinaceae

Casuarina equisetifolia L.

Seed sowed in 1923; not found subsequently.

Chenopodiaceae

Chenopodium oahuense (Meyen) Aellen
C. sandwicheum Moq. f. *microsperma* Aellen

Snyder (Albatross Expedition, see Fisher 1903a: 807), Caum 58 (BPBM), Christophersen 14 (BPBM), Kridler 2, 5 (UH), Long 2447, 2452, 2454, 2458 (UH).

Since 1923, at least, it has been the most common plant on Necker. Christophersen and Caum list it as being "abundant on the sloping sides, but rare on the flat top." In August 1968 and on other recent visits *Chenopodium* formed an almost pure stand in the saddle between Flagpole and Summit Hills (Fig. 12); it was abundant on the portion east of this region (Fig. 13) but somewhat less common on the tops of the hills than on the sloping sides and the saddle between them. It occurred in small amounts on the top of Flagpole Hill and was rare on both Annexation Hill and Northwest Cape.

Figure 12 Saddle between Summit and Flagpole Hills, August 1968. Note dense growth of Chenopodium. Photograph by Derral Herbst.

Figure 13 Saddle between Bowl and Summit Hills, August 1968. Note Chenopodium and Blue-faced Boobies. Photograph by Derral Herbst.

Aizoaceae

Sesuvium portulacastrum L.

Caum 93 (BPBM), Christophersen 12 (BPBM), Long 2456 (UH).

The Tanager Expedition members found this species growing within reach of the spray on the southern slopes of Annexation Hill. In September 1966 *Sesuvium* was most prevalent along the lower elevations where it would receive spray from the ocean (BSFW). In 1968 Herbst noticed one or two isolated plants on the northeast side of Annexation Hill. The rest of the sparse population was limited primarily to the southern slope near the top of the saddle between Annexation and Flagpole Hills. A similar pattern of distribution was noted by Long in September 1964 (POBSP).

Portulacaceae

Portulaca lutea Sol.

Gilbert (Albatross Expedition, USNM 594972), Caum 59 (BPBM), Christophersen 13 (BPBM), Kridler 4 (UH), Long 2457 (UH).

As in previous reports, *Portulaca* was common on the flat tops and ledges of the cliffs in August 1968. Except for a rare *Chenopodium* shrub, it was the only plant growing on Northwest Cape--in cracks and in shallow pockets of soil (Fig. 14). Some plants on the summit of Flagpole Hill appeared intermediate between *P. lutea* and *P. oleracea*.

Leguminosae

Haematoxylen campechianum L.

Seeds sowed in 1923; not found subsequently.

Sesbania tomentosa H. & A.

Gilbert (USNM 594974), Caum 57 (BPBM), Christophersen 11 (BPBM), Kridler 1 (UH), Long 2449, 2451, 2453, 2460 (UH).

Christophersen and Caum (1931) observed a few plants along the top of the main part of the island. Kramer (*in* Kramer and Beardsley, ms.) concurs and adds that it seemed "to be holding its own quite well" in June 1962. Kridler (BSFW), Long (POBSP) and Herbst (UH) found this shrub on the tops of all of the hills of the main island and Kridler found a few plants on Northwest Cape in March 1967. *Sesbania* is evidently more common now than Christophersen and Caum indicated.

Figure 14 Portulaca lutea Sol growing on the Northwest Cape. Note nesting Red-tailed Tropicbird in the left background. Photograph by Derral Herbst, August 1968.

Euphorbiaceae

Aleurites moluccana L.

Seeds found on the shores of Shark Bay in 1923 (Christophersen and Caum, 1931: 7).

Malvaceae

Thespesia populnea (L.) Sd.

Seeds sowed in 1923; not found subsequently.

Solanaceae

Solanum lycopersicum L.

Seeds sowed in 1923; not found subsequently.

TERRESTRIAL VERTEBRATES

Birds

Twenty-four species of birds have been recorded from Necker Island (Table 2). Of these 24, 15 are species of seabirds that breed at many localities in the central Pacific and two (Christmas Shearwater, Sooty Storm Petrel) are seabirds that breed commonly at other localities in the northwestern Hawaiian Islands but which as yet have not been found breeding on Necker. It seems likely that the absence of breeding Christmas Shearwaters may be largely due to a lack of suitable nesting habitat but the lack of records for the Sooty Storm Petrel may result primarily from the infrequency with which the island has been visited during the species' breeding peak in mid-winter. If the latter species does nest on Necker its population is probably small.

Of the seven remaining species, five are migrant and possibly winter resident shorebirds. Three of these five, Golden Plover, Wandering Tattler and Ruddy Turnstone, probably occur at Necker every year. The two others, the Sanderling and Bristle-thighed Curlew, are regular visitors to most of the other northwestern Hawaiian Islands but probably occur at Necker only sporadically.

The two remaining species are vagrants. One, the Glaucous-winged Gull, wanders fairly frequently to the main and northwestern Hawaiian Islands. The other, the Mockingbird, certainly wandered to Necker from the main Hawaiian Islands where introduced populations are well established on six islands (Berger, 1972: 215).

In addition to the 24 species known from the island, one other species, the Bonin Petrel (*Pterodroma hypoleuca*), was seen flying near Necker in September 1971. There is no evidence that this species

utilizes the island for roosting or nesting. It seems likely that these birds belonged to populations breeding on the northwestern Hawaiian Islands to the west.

Examination of the available data suggests that the breeding cycles of most of the birds of Necker Island are essentially similar to those found on the other Northwestern Hawaiian Islands. Two species, the Laysan and Black-footed Albatross, have clearly defined winter breeding peaks. The Black Noddy, which has a late winter and early spring breeding peak on other northwestern Hawaiian Islands, may have such a peak on Necker but the evidence for this is far from conclusive.

All other species, with the possible exception of the Sooty Tern, have breeding peaks that occur either in spring or summer but several species (e.g., Red-footed Booby, Brown Noddy) have such extended nesting seasons that some birds may be found nesting in every month of the year.

One species, the Sooty Tern, apparently nests earlier on Necker than on most of the other northwestern Hawaiian Islands. It appears to have a clinal series of breeding peaks along the chain with populations laying progressively later as one moves to the westward. On Necker the egg-laying peak apparently usually occurs in the period from January through early March while on Kure at the westernmost end of the chain, the laying peak usually occurs in May (Woodward, 1972: 250).

It is clear that much is yet to be learned about the status, maximum populations and breeding cycles of the birds of Necker Island. More surveys made during the mid-summer and mid-winter months would greatly help to clarify these matters.

Table 2. The avifauna of Necker Island

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
Order Procellariiformes		
Family Diomedeidae		
Diomedea nigripes Black-footed Albatross	Uncommon breeder	350* Mar. 1969
Diomedea immutabilis Laysan Albatross	Common breeder	1,650-2,000 Mar. 1965
Family Procellariidae		
Bulweria bulwerii Bulwer's Petrel	Common breeder	200+ Sept. 1966

Table 2. (continued)

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
Puffinus pacificus Wedge-tailed Shearwater	Common breeder	4,000-5,000 Sept. 1964
Puffinus nativitatis Christmas Shearwater	Rare visitor (two records)	1 Mar. 1967, 1969
Family Hydrobatidae		
Oceanodroma tristrami Sooty Storm Petrel	Rare visitor (one record)	1 Mar. 1965
Order Pelecaniformes Family Phaethontidae		
Phaethon rubricauda Red-tailed Tropicbird	Common breeder	200 Sept. 1966
Family Sulidae		
Sula dactylatra Blue-faced Booby	Common breeder	500 Mar. 1969
Sula leucogaster Brown Booby	Uncommon breeder	50 Sept. 1972
Sula sula Red-footed Booby	Common breeder	1,400* Mar. 1969
Family Fregatidae		
Fregata minor Great Frigatebird	Common breeder	2,000 Sept. 1966, 1971
Order Charadriiformes Family Charadriidae		
Pluvialis dominica Golden Plover	Uncommon migrant	6 Sept. 1967
Family Scolopacidae		
Numenius tahitiensis Bristle-thighed Curlew	Rare migrant	1 Sept. 1972
Heteroscelus incanus Wandering Tattler	Uncommon migrant	3 Sept. 1966

Table 2. (continued)

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
Arenaria interpres Ruddy Turnstone	Uncommon migrant	50 Mar. 1965
Calidris alba Sanderling	Rare migrant (one record)	0**
Family Laridae		
Larus glaucescens Glaucous-winged Gull	Vagrant (one record)	0**
Sterna lunata Gray-backed Tern	Abundant breeder	7,500* Mar. 1965
Sterna fuscata Sooty Tern	Abundant breeder	50,000 Mar. 1965
Procelsterna cerulea Blue-gray Noddy	Common breeder	2,000-3,000 Mar. 1967
Anous stolidus Brown Noddy	Abundant breeder	50,000 Sept. 1971
Anous tenuirostris Black Noddy	Common breeder	1,000 Mar. 1967
Gygis alba White Tern	Common breeder	600 Mar. 1967
Order Passeriformes Family Mimidae		
Mimus polyglottos Mockingbird	Vagrant (one record)	1 Sept. 1967

*Estimate is of the breeding population only.

+This, one of very few numerical estimates available, almost certainly understates the numbers of birds utilizing the island, as the estimate was made in a month (September) when the species was nearing the end of its breeding cycle. The maximum population inhabiting the island at any one time may well be five to ten times as great.

**A single bird was recorded in June 1923.

Species Accounts

Common names of seabirds follow King (1967) in the following species accounts. Taxonomic order follows that of Peter's (1931, 1934) Checklist of Birds of the World, volumes I and II, with the exception of Procellariformes which follow Alexander *et al.* (1965), the Charadriidae and Scolopacidae which follow Jehl (1968), and the Sulidae which follow the A.O.U. Checklist (1957). The scientific names of two shorebirds, the Wandering Tattler and Sanderling, have been modified following the latest supplement to the checklist (A.O.U., 1973).

The following species accounts are set forth in a standard format from which deviations are made only when warranted by lack of data. The section of the species accounts under Status lists maximum recent populations; delimits periods when birds occur most abundantly on the island, and, if the bird breeds there, briefly indicates the principal nesting habitat. It should be noted, except where otherwise indicated, that the population estimates are of the number of flying birds present on the island during any one visit; dependent non-flying young are not included. The section listed under Populations briefly evaluates recent numerical estimates, comparing them when possible with estimates or statements of abundance made by earlier visitors. In the Observation Tables a question mark indicates that the presence of birds was noted but that no estimates were made.

The section headed Annual Cycle uses all available data in an attempt to determine the regularity (or lack of it) in the breeding regimes of each species and by interpolation to determine periods during which birds breed. Data for Necker are less substantial than for most of the other islands considered in this series of reports and distinct conclusions sometimes could not be drawn. In the section headed Breeding Habitat is given a general summary of both previous and recent observations on nesting habitat. The section headed Banding lists all known bandings by the BSFW and POBSP. If the section is omitted, this indicates that no birds are known to have been banded. Very little banding has been done on Necker as compared with the other northwestern Hawaiian Islands. Only a total of 328 individuals of ten species was banded here by the POBSP and BSFW during the study period. Two interisland movements of banded birds involving Necker are known (see Great Frigatebird and Brown Noddy species accounts). Finally, the section headed Specimens lists the location of 91 specimens of 18 species, of which we are aware, that have been collected on the island. Hopefully this section will be of use to those interested in conducting taxonomic studies and will point out where further collecting might be useful.

BLACK-FOOTED ALBATROSS *Diomedea nigripes*

Status

Uncommon breeder (maximum recent breeding population estimate: 350). Known to be present from late December through late June, but probably present a month earlier and later; absent remainder of year. Nests on the ground on higher slopes of the island.

Populations

Estimates of breeding Black-footed Albatross are among the best obtained for any species for three reasons: the population is small and easily counted, the young are conspicuous, and albatrosses have been of particular interest to personnel visiting the island.

The estimate of June 1923 and most recent March estimates of breeding populations are much smaller than the estimate derived by an aerial survey in December 1957 (Table 3). On northwestern Hawaiian Islands the number of fledging young may be at times considerably less than the number of nests with eggs. This fact and variations in the number of young present on recent March visits make it impossible to be certain whether the 1957 estimate was erroneous, or whether the breeding population was actually larger then than in other years. The size of the albatross nesting population on Midway fluctuates from year to year; there is no reason to believe that the population on Necker does not vary also.

It is clear that the 1966-1967 population was either considerably smaller or considerably less successful than the 1964-1965 or 1968-1969 populations.

Annual Cycle

Too few data on breeding status are available to establish whether the breeding cycle on Necker is different from the cycle on other northwestern Hawaiian Islands. Available observations indicate a span of breeding from at least late December through June or perhaps early July. Young have been recorded from 10 March (1967) through 29 June (1923) but are probably present for at least a month prior to that period and for at least several weeks thereafter.

Breeding Habitat

In June 1923 Wetmore found young on the higher slopes among the Laysan Albatross. In March 1965 and 1969 Kridler noted that most nests were found on the upper slopes of Annexation and Flagpole Hills; no nests were found on Northwest Cape.

Banding

One young albatross was banded by the BSFW in March 1965.

Specimens

We have no record of any specimens of Black-footed Albatross from Necker Island.

Table 3. Observations of Black-footed Albatross on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	least abundant bird	Seen sparingly...(Fisher, 1903a: 777, 790).
1913	19 Mar.	?	Young present (Bailey, 1956: 32). A few nesting (Willett, ms.).
1916	27 Jan.	only a few*	Nesting (Munter, ms.).
	11 Feb.	several hundred	Island estimate, with eggs or very young chicks (Munter, ms.).
1923	17-20 June	200**	No adults but *ca*. 100 nearly grown young; a few young had down clinging to head and neck but many lacked any trace of down (Wetmore, ms.).
	29 June	200**	Young somewhat more developed (Wetmore, ms.).
1953	20 Dec.	200-300***	Nesting (Richardson, pers. comm.).
1957	28 Dec.	491(736)+	Nesting (Rice and Kenyon, 1962: 377).
1962	11 June	?	A few young seen (Kramer and Beardsley, ms.).
1964	8 Mar.	?	Numerous; *ca*. 130 seen in flight from offshore (POBSP).
	25-26 Sept.	0	(POBSP; BSFW).
1965	15 Mar.	375-400 (188-200**)	94 young counted; 100 estimated present (POBSP; BSFW).
1966	10-11 Sept.	0	(BSFW).
1967	10 Mar.	75 (50-60**)	*Ca*. 25-30 1/4- to 1/2-grown young seen (POBSP; BSFW).
1969	22 Mar.	350**	175 young counted. No more than 10 or 15 missed (BSFW).

Table 3. (continued)

Date of Survey	Population Estimate	Breeding Status, Remarks and References
1971 14 Sept.	0	(BSFW).
1973 20 July	0	(BSFW).

*Only westernmost peak examined.

**Estimate is of number of breeding birds.

***Only about half of island seen during survey.

+Data from aerial observations; figures are count of total birds and an estimate of breeding birds, based on an allowance for 25 percent unoccupied birds (736 was rounded to 740 by Rice and Kenyon, *op. cit.*).

LAYSAN ALBATROSS *Diomedea immutabilis*

Status

Common breeder (maximum recent breeding population estimate: 1,650-2,000). Recorded present and breeding late December to late July, but probably present from October through early August; not present during remainder of year. Nests on ground, principally on summits of hills and along topmost ridge of island.

Populations

Estimates of breeding populations of this species, like estimates for the preceding species, are relatively accurate and show practically the same degree of variation from survey to survey (Table 4).

It seems likely that current breeding populations are considerably smaller than indicated by Rice and Kenyon. However, estimates from May 1902 and June 1923 compare quite favorably with the recent March estimates. Thus we cannot conclude that there has been any real change in population size during the period for which we have data. It seems possible that Rice and Kenyon's count was biased upward by an inadvertent inclusion of Blue-faced or Red-footed Boobies; at present both species occur among the Laysan Albatross (Fig. 15).

Annual Cycle

Data on breeding status are few and poorly detailed but indicate a breeding cycle no different from that found on other northwestern Hawaiian Islands. June 1923, July 1964, and March 1967 and 1969

Figure 15   Young Laysan Albatross among Red-footed Boobies and Great Frigatebirds nesting in Chenopodium. Northwest Cape in the background. BSFW photograph by David B. Marshall, 11 June 1962.

observations reveal that this species has a later breeding cycle than has the Black-footed Albatross, an observation often noted in other areas where both breed.

Breeding has been recorded from late December through late July, and young have been noted from 10 March (1967) through 26 July (1964). Laysan Albatross are probably present from about late October through August as on Laysan.

Breeding Habitat

Observers who recorded nesting areas indicated Laysan Albatross nest primarily on the hilltops of the ridge running along the island. Fisher (1903a: 789) also found young "over the shelves on the side of the north point," which is evidently the area now called Northwest Cape. In March 1967 Hackman similarly noted a few young on rock shelves on cliff sides and slopes.

One observer specifically indicated where young were found. In July 1964 Kridler noted five young on the top of Annexation Hill, 11 on Flagpole Hill, 35 on Bowl Hill, and ten on the ridge extending east of Bowl Hill. In March 1969 he noted that the majority of the young was found on the upper slopes of Summit and Bowl Hills, with a few young in various locations along the ridges of the main part of the island. Less than 30 young were seen on the Northwest Cape.

Banding

BSFW personnel banded 100 young in March 1965.

Specimens

We have records of four specimens of Laysan Albatross from Necker: two males (USNM 300852, 300854) and two females (USNM 300853, 300857) collected by Wetmore 18 June 1923.

Table 4. Observations of Laysan Albatross on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	1,000-2,000	Young present (Fisher, 1903a: 789).
1913	19 Mar.	800*	Large downy young present (Bailey, 1956: 32). (Willett, ms.).
1916	27 Jan.	in large numbers**	Most with eggs, a few with very young chicks (Munter, ms.).
	11 Feb.	most numerous bird	Well incubated eggs and very young chicks (Munter, ms.).

Table 4. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1923	17-20, 29 June	1,200	Nearly grown young present; many with much down lost from head and neck and others with downy head and neck only (Wetmore, ms.).
1953	20 Dec.	600-800***	Nesting (Richardson, pers. comm.).
1957	28 Dec.	3,327 (4,990)+	Nesting (Rice and Kenyon, 1962: 377).
1962	11 June	?	Abundant young (Kramer and Beardsley, ms.).
1964	8 Mar.	numerous	From offshore *ca*. 800 seen on land and *ca*. 100 in flight (POBSP).
	26 July	140*	*Ca*. 70 young counted (BSFW).
	25-26 Sept.	0	(POBSP; BSFW).
1965	15 Mar.	1,650-2,200 (1,100*)	*Ca*. 550 young present (POBSP; BSFW).
1966	10-11 Sept.	0	(BSFW).
1967	10 Mar.	600 (300-400*)	*Ca*. 150-200 half-grown young seen (POBSP; BSFW).
	15 Sept.	0	(BSFW).
1969	22 Mar.	1,020-1,050*	Count of 510 young, 10-15 perhaps overlooked (BSFW).
1971	14 Sept.	0	(BSFW).
1973	30 July	?	Count of 40 fully-feathered young (BSFW).

*Estimate is of the number of breeding birds.

**Only westernmost peak examined.

***Only about half of island surveyed.

+Data from aerial observations; figures are a count of total birds and an estimate of breeding birds, based on an allowance for 25 percent unoccupied birds (4,990 was rounded to 5,000 by Rice and Kenyon, *op. cit.*).

231-338 O - 77 - 4

BULWER'S PETREL *Bulweria bulwerii*

Status

Common breeder (maximum recent estimate: 200). Breeds from at least late May through mid-September. Nests in holes in the rocks.

Populations

Too little information is available (Table 5) to adequately determine numbers present. The only numerical estimates probably do not begin to represent maximum numbers, since estimates were not made when birds would have been most abundant. We suspect that 1,000 or more petrels occur on the island but considerably more work is needed even to approximate numbers.

Annual Cycle

The few available observations on breeding status indicate that the species breeds annually. We have no evidence that the cycle differs from that on other northwestern Hawaiian Islands. Eggs are present from at least late May through late July, and young are present from about mid-July through September.

Breeding Habitat

Few notes have been made about nesting sites on Necker. Fisher (1903a: 794) gave the most detailed description: "Here the birds nest in rather deep, bubble-like holes in the rocks, as far from the light as possible....The favorite site...is a hole about 2 feet deep, with a narrow entrance, and wider cavity at the rear....The nest, scarcely worthy of the name, consists of a few old tern feathers gathered rudely around the egg, as if merely to hold it in place. Sometimes there is no trace of a nest, and again I found a few wing bones of a tern, as though these had been used in place of sticks." More recent observers found them nesting under stones and crevices on the sides of cliffs.

Banding

Two adults were banded by the BSFW in September 1964.

Specimens

We have records of nine specimens. Five males (USNM 189409, 189411-189413; SUI 18596) and three females (USNM 189407, 189408, 189410) were collected by Snyder, Fisher, and Nutting on 31 May 1902. One female (USNM 300800) was collected by Wetmore on 18 June 1923.

Table 5. Observations of Bulwer's Petrel on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	considerable numbers	Eggs and pre-laying birds (Fisher, 1903a: 777-794).
1913	19 Mar.	0	(Bailey, 1956: 32).
1923	17-20 June	common	Nesting (Wetmore, ms.).
	29 June	abundant	(Wetmore, ms.).
1953	20 Dec.	0*	None seen during diurnal survey (Richardson, pers. comm.).
1962	11 June	?	(Kramer and Beardsley, ms.).
1964	26 July	?	Eggs and young found (BSFW).
	25-26 Sept.	75-100	No eggs or young noted (POBSP; BSFW).
1965	15 Mar.	0	(POBSP;BSFW).
1966	10-11 Sept.	200	Two downy young found, one of them almost full grown (BSFW).
1967	10 Mar.	0	(POBSP;BSFW).
	15 Sept.	?	One young noted that was nearly fully feathered but retained a small amount of down on the head (BSFW).
1969	22 Mar.	0	None seen although a number of holes were examined (BSFW).
1971	14 Sept.	?	Several young found, all fully feathered except for large patches of down on the breast (BSFW).
1973	30 July	?	Many heard calling deep in burrows (BSFW).

*Only about half of island seen during survey.

WEDGE-TAILED SHEARWATER *Puffinus pacificus*

Status

Common breeder (maximum recent estimate: 4,000-5,000). Present from at least March through October; most breeding occurs from June through October. Most nest in holes or crevices at ground level, but a few dig burrows.

Populations

Since there are few numerical estimates (Table 6), and little banding has been done, it is impossible to state how many birds occur on the island. At least several thousand are present judging from the two maximal estimates. It is entirely possible that 10,000 or more may frequent the island.

Annual Cycle

Data on breeding are scanty but seem to conform to the general pattern found on other northwestern Hawaiian Islands. As on Nihoa, most birds evidently arrive in March but are not abundant until the latter half of the month. Birds probably court and dig burrows, where possible, for about two months before the first eggs are laid. Eggs are laid in June (1923) and are probably present through July (1964). The only observations made later in the breeding season were on three September visits (1964, 1966, 1967) when only downy young, most of them large, were seen. Most fledging presumably takes place in October and November.

Breeding Habits

On Necker these shearwaters nest mostly on or near the surface of the ground. Fisher (1903a: 792) stated that they nested in hollow cavities in the rocks. Kridler recently found them nesting in holes and depressions in rock rubble and along the upper cliff sides. He noted a number nesting under *Chenopodium* on the surface of the ground (particularly on the west slope of Flagpole Hill), and occasionally in burrows beneath the *Chenopodium*.

Banding

In March 1964 POBSP personnel banded 19 adult Wedge-tailed Shearwaters. None was recaptured.

Specimens

We have records of seven specimens of Wedge-tailed Shearwaters from Necker. Three males (USNM 240995, 250996, 240998) and one female (USNM 240997), collected by Willett, and one male (UMMZ 120133) collected by Bailey, were taken on 19 March 1913. A male (USNM 300722) and a female (USNM 300721) were collected by Wetmore on 18 June 1923.

Table 6. Observations of Wedge-tailed Shearwaters on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	?	Nesting but no eggs (Fisher, 1903a: 792).
1913	19 Mar.	abundant	Mating and nest building but no eggs found (Bailey, 1956: 32).
1916	27 Jan.	?	Some seen flying about at dusk (Munter, ms.).
1923	17-20, 29 June	6,000	Eggs present (Wetmore, ms.).
1953	20 Dec.	0*	None seen during diurnal survey (Richardson, pers. comm.).
1962	11 June	?	Kramer and Beardsley, ms.).
1964	8 Mar.	?	Few seen from offshore (POBSP; BSFW).
	26 July	very common	Many nests contained eggs (BSFW).
	25-26 Sept.	4,000-5,000	An estimated 1,500 downy young present (POBSP; BSFW).
1965	15 Mar.	2,000	No eggs or young found (POBSP; BSFW).
1966	10-11 Sept.	abundant	Only large downy young seen (BSFW).
1967	10 Mar.	10	Estimate represents number of birds seen, not number of birds present. No eggs found (POBSP; BSFW).
	15 Sept.	common	*Ca.* 118 downy young counted, most of them large; 8 eggs found (BSFW).
1969	22 Mar.	4,000	Almost all birds observed were in pairs (BSFW).
1971	14 Sept.	very common	All chicks seen were large and downy (BSFW).
1972	15 Sept.	?	(BSFW).
1973	30 July	?	At least 275 nesting adults present (BSFW).

*Only about half of island seen during survey.

CHRISTMAS SHEARWATER *Puffinus nativitatis*

Status

Rare visitor, two March sight records.

Observations

Richardson (1957: 17) suggested that this shearwater breeds on Necker, but the near absence of records by several competent observers at times when breeding should be at its peak indicates that such is not the case. There are only two records, hitherto unpublished. On 10 March 1967 Kridler saw a single individual near the landing area; on 22 March 1969 BSFW personnel observed another.

SOOTY STORM PETREL *Oceanodroma tristrami*

Status

Rare visitor; one March sight record.

Observations

The only record is of an adult found by Kridler on 15 March 1965; it was thought to have been dead about a week.

RED-TAILED TROPICBIRD *Phaethon rubricauda*

Status

Common breeder (maximum recent estimate: 200). Present throughout most of year but probably much less abundant in late fall, winter and early spring. Most breeding probably occurs between early April and early October. Nests primarily in crevices and hollows in the rocks.

Populations

The maximum estimate given above is probably a poor indication of maximal numbers since it was made late in the year when populations should be smaller than during the probable breeding peak. Wetmore's estimate of 1,000 birds made in June 1923 probably better represents maximal numbers, both then and in recent years.

Annual Cycle

Tropicbirds on Necker evidently have an extended nesting season (Table 7) similar to that on other northwestern Hawaiian Islands. The presence of near-fledging young (at least two months old) in late July 1964 indicates that egg laying can occur by mid-April; it is likely that some birds lay even earlier. Eggs are presumably present from then at least through September. Young are present at least from late May through December or January.

Various March observations imply that populations and breeding decrease considerably late in the year and suggest that little breeding occurs until early April.

Breeding Habitat

On Necker these tropicbirds nest principally in rock crevices. Fisher (1903a: 796) noted that tropicbirds "accomodated [themselves] to the rocks and [laid eggs] in any rounded cavity" and Wetmore (ms.) noted that several pairs could be found nesting eight to 20 feet apart under a single over-hanging ledge. Kridler noted that shallow small caves on ledges along the upper portions of Bowl, Summit, and Flagpole Hills were favored as nest sites, as were crevices on the upper western slopes of Northwest Cape.

Banding

The POBSP banded three adults and 18 young in September 1964; none was subsequently recaptured.

Specimens

Two females (USNM 300986, 300987) were collected by Wetmore on 17 June 1923, and are now in the National Museum of Natural History.

Table 7. Observations of Red-tailed Tropicbirds on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	rather common	Nesting, at least some eggs (Fisher, 1903a: 796).
1913	19 Mar.	1	(Bailey, 1956: 32).
1923	17-20 June	1,000	Fresh eggs to recently hatched young (Wetmore, ms.).
1953	20 Dec.	?*	Still unfledged young present (Richardson, 1957: 19).
1962	11 June	?	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	Four seen in flight from offshore (Walker, ms.).
	26 July	?	Eggs to nearly full-grown young noted in ten nests found (BSFW).
	25-26 Sept.	125	25 nests with near-fledging young counted and a few eggs seen (POBSP; BSFW).

Table 7. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1965	15 Mar.	0	(POBSP; BSFW).
1966	10-11 Sept.	200	72 nests with young, mostly large, and 1 nest with egg counted (BSFW).
1967	10 Mar.	15	Birds in courtship flight; no nests found (POBSP; BSFW).
	15 Sept.	?	23 young from small downy chicks to near-fledging young seen, 15 adults seen (BSFW).
1969	22 Mar.	20	No eggs or young found (BSFW).
1971	14 Sept.	?	All young seen were very large (BSFW).
1972	15 Sept.	?	(BSFW).
1973	30 July	95**	Young seen (BSFW).

*Only about half of island seen during survey.

**Estimate is of adults and young.

BLUE-FACED BOOBY *Sula dactylatra*

Status

Common breeder (maximum recent estimate: 500). Present and breeding in all months, but most breeding occurs from February through late September or early October. Nests on the ground on the higher slopes.

Populations

Recent estimates from March and September surveys consistently indicate populations of 200 to 250 birds (Table 8). There are no recent summer estimates for Blue-faced Booby populations on Necker; however, comparisons of March, summer, and fall estimates on other northwestern Hawaiian Islands indicate that summer populations are not much larger than spring or fall populations. Thus we suspect that Necker mid-summer populations seldom exceed 500 to 600 birds. This figure is considerably less than that reported for June 1923 by Wetmore and may indicate that populations were formerly larger.

Annual Cycle

Data on the breeding cycle were primarily obtained during March and September but they afford us some idea of its duration and nature. Egg laying began as early as late November (1964) or early December (1913). Data on breeding status from March visits indicate that much greater numbers of eggs are laid from mid- or late January through March than in the preceding months.

The smallest young present on all recent September visits were probably no less than two or three months old. This suggests that most laying ceases by about mid-June, although eggs are possibly present through early August. This laying span is similar to that found on other northwestern Hawaiian Islands such as Nihoa and Laysan and implies that other features of the breeding season are also similar. If this is true, then we would expect that the hatching peak occurs about May and June and that the fledging peak occurs from about late August to perhaps early October.

The length of the periods during which hatching and fledging occur is considerably longer. Hatching has occurred from early or mid-January (1965) to as late as August. Fledging has probably occurred as early as May and certainly continues through October, with a few chicks possibly fledging in November.

Thus, on Necker, as on other northwestern Hawaiian Islands, the Blue-faced Booby has nested in all months of the year. It is possible, however, that breeding may not occur in all months every year and that there are yearly variations in the breeding cycle which cannot be detected from the available data.

Breeding Habitat

All observers who noted where these birds nested indicated they nested on the higher slopes of the island. Fisher (1903a: 797) stated that the Blue-faced Boobies were "nesting among the bushes on the top of the island, and also out on the bare rocks. They chose often a jutting crag, where they could obtain a good prospect of the surrounding island and sea." On several subsequent visits (June 1923, July 1964, March 1965, 1967, 1969) other observers reported these birds nesting on the higher slopes, the summit of the island, or along the ridge in more bare areas.

On Necker Blue-faced Boobies usually have well-separated nest sites.

Banding

Fifty adults were banded by the BSFW in March 1965.

Specimens

We have records of only two specimens from Necker, both of which are in the USNM. Both are adult females (USNM 300940, 300941) collected by Wetmore on 18 and 19 June 1923.

Table 8. Observations of Blue-faced Boobies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	rather abundant	The few nests examined had young (Fisher, 1903a: 797).
1913	19 Mar.	common	Eggs to large young (Bailey, 1956: 32).
1916	27 Jan.	small numbers*	No eggs or young (Munter, ms.).
	11 Feb.	large numbers**	A very few with eggs; two nearly full grown young (Munter, ms.).
1923	17-20 June	1,000	Young from half to nearly grown (Wetmore, ms.).
1953	20 Dec.	100-150***	(Richardson, pers. comm.).
1962	11 June	present	(Kramer and Beardsley, ms.).
1964	8 Mar.	25	Seen from offshore (POBSP; BSFW).
	26 July	?	Eggs to flying young (BSFW).
	25-26 Sept.	250	Count of 58 adults, 57 immatures and 60 locals (POBSP; BSFW).
1965	15 Mar.	230	Count of 110 nests; all with eggs except for one with an egg and recently hatched young and one with a large downy young (POBSP; BSFW).
1966	10-11 Sept.	200	Some young still dependent but all of fledging size (BSFW).
1967	10 Mar.	210	All on eggs except for three pairs with recently hatched young (out of a count of 103 nests) (POBSP; BSFW).
	15 Sept.	240	Count of 204 adults and 32 flying immatures; 6 downy chicks counted (BSFW).

Table 8. (continued)

Date of Survey	Population Estimate	Breeding Status, Remarks and References
1969 22 Mar.	500	Count of 230 nests. Sample count of 101 nests: 6% without eggs; 63% with eggs; 16% with an egg and one young, and 15% with young (BSFW).
1971 14 Sept.	200	Estimate includes 40 young (BSFW).
1972 15 Sept.	?	(BSFW).
1973 30 July	190	Estimate includes young (BSFW).

*Only westernmost peak examined.

**Only the eastern part of the island surveyed.

***Only about half of island seen during survey.

BROWN BOOBY *Sula leucogaster*

Status

Uncommon breeder, but poorly known (maximum recent estimate: 50). Present and probably has bred in all months of the year. Nests on ground along the higher elevations of the island or on cliff ledges.

Populations

Recent estimates consistently suggest that 50 or fewer Brown Boobies occur on Necker (Table 9). These estimates are possibly too low since at least some proportion of the population nests in inaccessible and seldom-observed areas on the rock cliffs. Wetmore's estimate (100 birds in June 1923) is considerably larger than recent estimates and may best represent current populations.

Annual Cycle

We have too few data on breeding to accurately delineate the major features of the breeding season. Available data suggest that breeding can occur in all months of the year and that eggs and young have been present in all months, although not necessarily during any one year. The data also suggest that most nesting occurs in spring and summer, as on other northwestern Hawaiian Islands.

Breeding Habitat

Very little information on nesting habitat has been recorded here. Fisher (1903a: 798) merely noted that "The two eggs [were] laid on a level place, where there happens to be a little soil, upon a shelf of the rock." Wetmore and more recent visitors observed them nesting on rock ledges and along the top of the island. Observations from two recent surveys (March 1965 and September 1967) indicate that these boobies nested more commonly on the Northwest Cape than on the main portion of the island.

Specimens

We have found records of three specimens of Brown Boobies from Necker: a female (USNM 189414), collected by Fisher on 31 May 1902, and a male and female (USNM 300858, 300859), collected by Wetmore on 19 and 20 June 1923, respectively.

Table 9. Observations of Brown Boobies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	not at all abundant	Fresh eggs to large downy young (Fisher, 1903a: 798).
1913	19 Mar.	2	(Willett, ms.).
1923	17-20 June	100	One or two half-grown young seen (Wetmore, ms.).
1953	20 Dec.	0*	(Richardson, pers. comm.).
1962	11 June	present	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	*Ca.* 50 seen from offshore (POBSP; BSFW).
	26 July	?	A nest with two eggs found (BSFW).
	25-26 Sept.	15	Count of eight adults and three flying immatures. No nests seen (POBSP; BSFW).
1965	15 Mar.	25	Ten nests counted, most with eggs. One nest with a near-fledging chick and one with a small downy young observed (POBSP; BSFW).
1966	10-11 Sept.	?	No young or eggs found (BSFW).

Table 9. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1967	10 Mar.	10	Not breeding (POBSP; BSFW).
	15 Sept.	10	Count of six adult and three flying immatures. A large downy young and a nest or nests with eggs seen (BSFW).
1969	22 Mar.	40**	Count of 20 nests, all containing eggs (BSFW).
1971	14 Sept.	10	Four adults and two flying immatures seen (BSFW).
1972	15 Sept.	50	(BSFW).

*Only about half of island seen during survey.

**Estimate is of the number of breeding birds.

RED-FOOTED BOOBY *Sula sula*

Status

Common breeder (maximum recent estimate: 1,400). Present and may breed throughout the year, but most nesting usually occurs from February or March through September or October. Builds bulky nests in the tops of *Chenopodium* bushes.

Populations

The few recent numerical estimates (Table 10) are reasonably consistent except for the differences in the March estimates for 1965 and 1967. The difference in these estimates is partly a result of the difference in the breeding cycle in these two years (see Annual Cycle below).

A single early estimate (2,000 in June 1923) is larger than any recent estimate (1,400 in March 1969) but is not enough so that we can conclude that there has been any change in numbers. Since the largest recent estimate was made relatively early in the breeding season, when all birds might not have returned to the island, we suspect that maximal populations at the present time may be as much as a third or a half again larger (to perhaps as many as 2,000 birds).

Annual Cycle

This species has a very extended breeding season on Necker and, in some years, may nest in all months. Most of the population, however, nests from March (or perhaps February) through about mid-October.

Laying has begun at least as early as early January (1913) and has probably occurred in all subsequent months through September. Since nothing larger than small young was seen on any of four March visits (1913, 1965, 1967, 1969), it is likely that eggs are usually not laid from October through December. Observations from those four March visits also indicate that the timing of the initiation of laying varies from year to year. Initiation of breeding appears to have been earlier in 1965 and 1969 than in 1967 (see also Great Frigatebird account).

In most years most fledging probably occurs from August through October. If the eggs seen in September 1964 and 1967 were viable and produced young, however, fledging could have occurred in December and January.

Breeding Habitat

Various observers agree that most Red-footed Boobies on Necker nest in the tops of *Chenopodium* bushes. A few nests have been found on the stone ruins and in *Sesbania*. Several observers (Fisher, 1903a: 797; BSFW) indicated that this species nests principally on the higher slopes of the island. On various March visits and in September 1966 Kridler noted that most nests were found on the north slopes of the main portion of the island. Red-footed Boobies have not been recorded nesting on Northwest Cape where no *Chenopodium* grows.

Banding

A single adult was banded by the BSFW in March 1965.

Specimens

We know of only three specimens (USNM 300906-08); they were collected 19 June 1923 by Wetmore.

Table 10. Observations of Red-footed Boobies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	abundant	Eggs and young common (Fisher, 1903a: 797).
1913	19 Mar.	common	New nests to small young (Bailey, 1956: 32).

Table 10. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1916	11 Feb.	quite common*	None found nesting. About 30 immatures seen (Munter, ms.).
1923	17-20 June	2,000	Most nests with 1/3 to 1/2 grown young, a few with eggs, and some recently built nests (Wetmore, ms.).
1953	20 Dec.	200-300**	(Richardson, pers. comm.).
1962	11 June	?	(Kramer and Beardsley, ms.). A photograph by Marshall shows birds on nests and a near-fledging young.
1964	8 Mar.		Few seen from offshore (POBSP).
	26 July	?	Eggs to downy young (BSFW).
	25-26 Sept.	650	Most nests contained young. 97 nests were counted but contents are known for only 72: 27 (38%) contained eggs; 22 (31%) contained small or medium-sized young, and 23 (32%) contained large young. 64 immatures capable of flight were also counted (POBSP; BSFW).
1965	15 Mar.	1,000***	Count of 412 nests and an estimated 500 present. All contained eggs (POBSP; BSFW).
1966	10-11 Sept.	?	More than 95% of young had fledged. Some dependent immatures and less than ten downy young observed (BSFW).
1967	10 Mar.	350	Mostly pre-breeding birds, three nests of 100 checked had eggs (POBSP; BSFW).
	15 Sept.	550	Count of 420 adults and 95 flying immatures. 76 nests counted: 17 (22%) with eggs and 59 (78%) with young. An additional 17 new nests as yet lacking eggs counted (BSFW).
1969	22 Mar.	1,400***	Count of 700 nests with perhaps a few having been overlooked. Of 118 nests inspected, 30% were new, but empty, and 70% contained eggs (BSFW).

Table 10. (Continued)

Date of Survey	Population Estimate	Breeding Status, Remarks and References
1971 14 Sept.	425	47 nests contained chicks, most of them 1/2 grown (BSFW).
1972 15 Sept.	700	(BSFW).
1973 30 July	108	Estimate is of adults and dependent young (BSFW).

*Only the eastern part of the island explored.

**Only about half of island seen during survey.

***Estimate is of the number of breeding birds present.

GREAT FRIGATEBIRD *Fregata minor*

Status

Common breeder (maximum recent estimate: 2,000). Present throughout the year but less abundant in winter. Breeding birds present in all months but primary nesting period is from March through October or November. Builds bulky nests in *Chenopodium* bushes, primarily at higher elevations.

Populations

Recent estimates consistently indicate populations in the low thousands (Table 11). The single December estimate suggests that populations may decrease by as much as three-quarters when breeding is mostly completed. The remarkable similarity in the nest counts of March 1965 and 1969 (832 vs. 850) suggests a similar correspondence in the breeding cycles these years. The distinct difference between the 1965, 1969 March estimates and the 1967 March estimate parallels the difference in Red-footed Booby estimates for those months and probably has the same cause, an earlier initiation of breeding in 1965 and 1969 than in 1967.

The single early numerical estimate (600 in June 1923) is lower than most recent estimates, enough so that it seems likely that either the size of the population has increased or possibly that 1923 was a particularly unfavorable year for breeding.

Annual Cycle

Populations breed on an annual basis but exhibit an extended breeding season in which nesting probably occurs in all months. The near absence of observations from winter months limits our analysis of the nesting season but observations from March and September indicate that only a very small proportion of the nesting population has unfledged young in January and February and that no eggs are present from September through about February.

A few eggs may be laid in late February but most egg laying occurs in March and April. The presence of eggs in late July (1964) implies that egg laying continues from March at least through May. Hatching occurs primarily in May or June but may occur as late as early August.

The first young probably fledge in early or mid-September but may remain dependent on the adults for at least several more months. Most young fledge from about late October through November but Richardson's observations indicate that some young may not have fledged by January or even February. The immatures seen by Kridler in July 1964 were young from the preceding nesting seasons.

Breeding Habitat

On Necker Great Frigatebirds nest in the same areas and habitat as do Red-footed Boobies. Most build bulky nests about a foot to a foot and a half above the ground in dense *Chenopodium* bushes and in almost every *Sesbania* bush found along the ridges and higher slopes. Fisher (1903a: 799) reported that "A few had nests on the rocks, generally on jutting crags." On recent March visits frigatebirds were found nesting all over the north slopes of Summit and Flagpole Hills among the Red-footed Boobies and other nests were found scattered over the ridges and tops of the other parts of the main island. In March 1965 Kridler noted that the majority nested on the north slopes of Summit Hill but that none nested on the Northwest Cape.

Banding and Movements

No frigatebirds have been banded on Necker. However, on 10 and 11 September 1966 Kridler saw an immature bird with an orange streamer on its left leg. Orange plastic leg streamers were placed on frigatebirds by the POBSP only on Sand Island, Johnston Atoll, about 560 nautical miles to the south-southwest.

Specimens

We found records of three Great Frigatebird specimens from Necker. An immature male (USNM 189416) was collected 31 May 1902 by Fisher and Snyder, and a male and a female (USNM 465205, 300971) were collected 18 June 1923 by Wetmore.

231-338 O - 77 - 5

Table 11. Observations of Great Frigatebirds on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1891	28 May	?	Seen offshore (Munro, 1941b: 51).
1902	31 May	large numbers	Nesting, displaying males seen (Fisher, 1903a: 777, 799).
1913	19 Mar.	several small colonies	Eggs present (Bailey, 1956: 32).
1916	27 Jan.	?*	No nests found. Only seen roosting (Munter, ms.).
	11 Feb.	very numerous**	None found nesting. Females apparently more common than males (Munter, ms.).
1923	17-20 June	600***	Eggs to one-third grown young (Wetmore, ms.).
1953	20 Dec.	400-600+	All young flying except for two half-grown young (Richardson, 1957: 23; and pers. comm.).
1962	11 June	present	Nesting (Kramer and Beardsley, 1962).
1964	8 Mar.	?	Males with inflated throat pouches seen from offshore. *Ca*. 2,000 seen on land and *ca*. 1,500 in flight (POBSP).
	26 July	*Ca*. 500**	Eggs to half-grown young. Many immatures seen flying (BSFW).
	25-26 Sept.	1,500-1,800	Eight small downy nestlings; 85 large young and 375 immatures counted. Observations indicate a *ca*. 50% nest failure (POBSP; BSFW).
1965	15 Mar.	2,000	832 nests counted and an estimated 850 present (POBSP; BSFW).
1966	10-11 Sept.	2,000	*Ca*. 200 dependent young still on nests, a few of which were downy young (BSFW).
1967	10 Mar.	500	Most birds building or with recently completed nests. Thirty-seven of 100 active nests with eggs. An estimated 200 nests present (POBSP; BSFW).

Table 11. (continued)

Date of Survey	Population Estimate	Breeding Status, Remarks and References
1967 15 Sept.	1,200	Many half- to nearly full-grown young (BSFW).
1969 22 Mar.	1,900-2,000	Count of 850 nests. Of 112 nests whose contents were checked, 42% were new but empty; 56% contained one egg and 2% contained two eggs. One almost full-grown young with a trace of down on the head and more than two hundred flying immatures also seen (BSFW).
1971 14 Sept.	2,000	A minimum of 478 nests present containing two-thirds to almost full-grown young (BSFW).
1972 15 Sept.	835	Estimate believed to be low. Most birds seen were adults and flying immatures (BSFW).
1973 30 July	374	Partial count of chicks and adults (BSFW).

---

*Only westernmost peak examined.

**Only the eastern part of the island visited.

***Estimate is of the number of breeding birds.

+Only about half of island seen during survey.

GOLDEN PLOVER *Pluvialis dominica*

Status

Uncommon migrant (maximum recent estimate: 6). Recorded in March, June, and September.

Observations

All observations are listed in Table 12.

Specimens

The only specimen (USNM 301057) is a female collected 20 June 1923 by Wetmore.

Table 12. Observations of Golden Plovers on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	0	(Fisher, 1903a).
1913	19 Mar.	0	(Bailey, 1956: 32).
1923	17-20 June	?	One female collected on 20 June (Wetmore, ms.).
1953	20 Dec.	0*	(Richardson, pers. comm.).
1964	26 July	?	(BSFW).
	25-26 Sept.	3	(POBSP; BSFW).
1965	15 Mar.	0	(POBSP; BSFW).
1966	10-11 Sept.	4	(BSFW).
1967	10 Mar.	2	(POBSP; BSFW).
	15 Sept.	6	(BSFW).
1969	22 Mar.	0	(BSFW).
1971	14 Sept.	0	(BSFW).
1972	15 Sept.	0	(BSFW).
1973	30 July	0	(BSFW).

*Only about half of island seen during survey.

BRISTLE-THIGHED CURLEW *Numenius tahitiensis*

Status

Rare migrant (maximum recent estimate: 1). Recorded in September.

Observations

A single bird seen near the east end by Kridler on 15 September 1972 constitutes the only record for Necker Island. The species is of regular occurrence on the other Northwestern Hawaiian Islands.

WANDERING TATTLER *Heteroscelus incanus*

Status

Uncommon migrant (maximum recent estimate: 3). Recorded in March, May, June, and September.

Observations

All observations are listed in Table 13.

Specimens

The only specimen (USNM 301028) is a male collected 19 June 1923 by Wetmore.

Table 13. Observations of Wandering Tattlers on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	?	(Fisher, 1903a: 778).
1913	19 Mar.	0	(Bailey, 1956: 32).
1923	17-20 June	1-2	Seen daily; a male collected 19 June (Wetmore, ms.).
1953	20 Dec.	0*	(Richardson, pers. comm.).
1964	26 July	?	(BSFW).
	25-26 Sept.	1	(POBSP; BSFW).
1965	15 Mar.	0	(POBSP; BSFW).
1966	10-11 Sept.	3	(BSFW).
1967	10 Mar.	1	(POBSP; BSFW).
	15 Sept.	0	(BSFW).
1969	22 Mar.	0	(BSFW).
1971	14 Sept.	0	(BSFW).
1972	15 Sept.	0	(BSFW).
1973	30 July	0	(BSFW).

*Only about half of island seen during survey.

RUDDY TURNSTONE *Arenaria interpres*

Status

Uncommon migrant (maximum recent estimate: 50). Recorded in March, May to July, September, and December.

Observations

Although never occurring in large numbers, turnstones are the most abundant and most frequently seen shorebird that visits Necker (Table 14).

Specimens

The only specimen (USNM 393503) is a male collected 20 June 1923 by Wetmore.

Table 14. Observations of Ruddy Turnstones on Necker Island

Date of Survey		Population Estimate	Observations, Remarks and References
1902	31 May	a few	(Fisher, 1903a: 803).
1913	19 Mar.	1-2	(Willett, ms.).
1916	11 Feb.	fairly common*	Scattered about island (Munter, ms.).
1923	17-20 June	20	A male collected 20 June (Wetmore, ms.).
1953	20 Dec.	20-30**	(Richardson, pers. comm.).
1964	26 July	several	Seen at the top of the easternmost peak (BSFW).
	25-26 Sept.	23*	(POBSP; BSFW).
1965	15 Mar.	50	30 seen in one flock (POBSP; BSFW).
1966	10-11 Sept.	11*	(BSFW).
1967	10 Mar.	22	One flock of 12 seen flying over Shark Bay. Solitary birds observed along the ridge (POBSP; BSFW).
	15 Sept.	37***	A flock of 30 seen. Another flock of seven seen on Northwest Cape (BSFW).
1969	22 Mar.	2	(BSFW).

Table 14. (continued)

Date of Survey	Population Estimate	Observations, Remarks and References
1971 14 Sept.	<10	(BSFW).
1972 15 Sept.	2	(BSFW).
1973 30 July	30	Seen in one flock (BSFW).

*Only eastern part of the island explored.

**Only about half of island seen during survey.

***Count.

SANDERLING *Calidris alba*

Status

Rare migrant; one June sight record.

Observations

Wetmore (ms.) noted that one was reported by Grant on 19 June 1923. This record, hitherto unpublished, constitutes the only known occurrence of the Sanderling on Necker Island.

GLAUCOUS-WINGED GULL *Larus glaucescens*

Status

Vagrant; a single June specimen record.

Observations and Specimens

A dead immature, found on the beach 18 June 1923, and subsequently collected by Wetmore (USNM 489329), was reported by Clapp and Woodward (1968: 27).

GRAY-BACKED TERN *Sterna lunata*

Status

Abundant breeder (maximum recent estimate: 7,500). Present from at least February through September or October, probably absent or

occurring only as a visitor during the rest of the year. Breeds from at least March (and occasionally February) through September or October. Nests on the ground, on rock cliffs, or open slopes.

Populations

No recent numerical estimates (Table 15) are available for months when the population is presumably near its peak (April-June). The largest recent numerical estimate (March 1965) was very similar to that obtained in June 1923 suggesting that present populations are as large if not larger than in 1923. Since few birds were seen in September (1964, 1966, 1967) and December (1953), it seems likely that the entire population departs the island after breeding.

Annual Cycle

No observations are available that indicate when birds first arrive at the island but data from March surveys indicate that egg laying usually begins in March but may occasionally occur in February (1916, 1967?). Some egg laying occurs during succeeding months through about July but the peak laying period occurs from about late March through mid-May. Hatching young are present from about early April through about late August and young fledge from about early or mid-June through late September.

Breeding Habitat

Gray-backed Terns nest primarily on ledges on the cliffs and upper slopes of the island. Fisher (1903a: 781) found them nesting "in shallow cavities and hollows of the rock on more exposed portions of the island, and only very sparingly on the broad shelves with *Sterna fuliginosa* [=*fuscata*]." Wetmore (ms.) stated "they were nesting on ledges of cliffs and open slopes of the island." More recently, observers have found them nesting commonly on broad rock shelves, particularly on the Shark Bay side of Northwest Cape. Others nested on the inaccessible cliffs and on the various slopes of the main island as well as the upper portion of Northwest Cape. On Necker, the Gray-backed Terns seem to favor more elevated areas for nesting to a greater degree than does their congener, the Sooty Tern.

Specimens

Wetmore is apparently the only visitor who collected Gray-backed Terns on Necker Island. On 18 and 20 June 1923 he collected five specimens, three males (USNM 300630, 300631, 300645) and two females (USNM 300632, 300646). Two of these (USNM 300645, 300646) were young birds.

Table 15. Observations of Gray-backed Terns on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	many observed	Nesting (Fisher, 1903a: 781).
1913	19 Mar.	common	Eggs (Bailey, 1956: 32).
1916	11 Feb.	not very numerous*	Only eggs found (Munter, ms.).
1923	17-20 June	8,000	From eggs to near fledging young (Wetmore, ms.).
1953	20 Dec.	2**	Not breeding (Richardson, pers. comm.).
1962	11 June	present	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	*Ca.* 200 seen in flight from offshore (POBSP; BSFW).
	26 July	at least several thousand	Many near-fledging young present (BSFW).
	25-26 Sept.	3	Not breeding; 2 immatures still present (POBSP; BSFW).
1965	15 Mar.	7,500***	Eggs (POBSP; BSFW).
1966	10-11 Sept.	?	Few adults seen. Over 25 flightless but nearly full-grown young observed. Several 2/3-grown young seen (BSFW).
1967	10 Mar.	500	Fresh to lightly incubated eggs (POBSP; BSFW).
	15 Sept.	20	17 adults counted. Three large near-fledging young seen (BSFW).
1969	22 Mar.	1,300	About 25% on eggs (BSFW).
1971	14 Sept.	?	No adults seen. A number of large young, some fledged, present (BSFW).
1972	15 Sept.	?	(BSFW).
1973	30 July	370***	160 chicks of varying sizes seen and about 25 birds were on eggs. Estimate probably too low (BSFW).

Table 15. (continued)

---

*Only eastern part of the island explored.

**Only about half of island seen during brief survey.

***Estimate is of the breeding population.

SOOTY TERN *Sterna fuscata*

Status

Abundant breeder (maximum recent estimate: 50,000). Present from about December or January through about late September; probably absent during remainder of year. Has bred from early December through September but most breeding probably occurs from February through August. Nests on the ground in bare areas on slopes and cliff ledges or under dense *Chenopodium* bushes.

Populations

Recent estimates (Table 16) indicate that the Sooty Tern is the most abundant breeder on Necker. As with the Gray-backed Tern, the smaller September and December estimates indicate this species is absent from the island during the non-breeding season.

Annual Cycle

Sooty Terns breed annually on Necker Island, but their nesting season is significant in that here it apparently regularly begins earlier than on almost any of the other northwestern Hawaiian Islands. The March 1913 observations indicate that laying must have occurred at least as early as mid-February while the presence of near-fledging young on two recent March visits (1965, 1967) indicates some laying began at least by early December (1964) or early January (1965). The beginning of laying may vary considerably from year to year. The size of the young reported by Fisher suggests that laying did not begin until about late April in 1902.

Laying continues from January or February through June (1923) and in some years (1966) possibly occurs into early July. Hatching has occurred from about mid-January to early February through about late July or early August and fledging young have occurred from early March through about mid-September. The small numbers of fledged and near-fledging young seen on September visits, however, suggest that most fledging was completed at least a month earlier.

Breeding Habitat

Sooty Terns have been recorded nesting in many different areas of the island (Fig. 16). Fisher (1903a: 780) reported that these terns laid "their eggs on the shelves of rocks where there [were] some soil and matted succulent portulacas....A few eggs...were laid in cavities in the face of the rock...many eggs were laid out on the bare rock in the full glare of the sun...a few perilously near high-water mark, in fact wet with spray." On recent visits colonies were found all over the island. Birds nested on bare rocks on Northwest Cape and the main part of the island and under *Chenopodium* from above the cliffs to the tops of the ridges. In September 1966, when the breeding season was nearly over, a few young were found on the west slope of Flagpole and Summit Hills and on the north slope of Annexation Hill.

Specimens

We have found records of six specimens collected on Necker Island: Fisher collected a juvenile male (USNM 189430) on 31 May 1902 and Wetmore collected three males (USNM 300541, 300545, 300547) and few females (USNM 300542, 300546) on 18 and 20 June 1923. Two of these birds (USNM 300546-547) are juveniles.

Table 16. Observations of Sooty Terns on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	most abundant bird	Heavily incubated eggs and recently hatched young, some chicks 7-10 days old (Fisher, 1903a: 780).
1913	19 Mar.	thousands	Eggs and small young (Bailey, 1956: 32).
1916	11 Feb.	very abundant*	Fresh eggs to near-fledging young (Munter, ms.).
1923	17-20 June	30,000	Fresh eggs to grown young; fledged young present on 29 June (Wetmore, ms.).
1953	20 Dec.	1**	Not breeding (Richardson, pers. comm.).
1962	11 June	most abundant bird	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	Hundreds seen from offshore (POBSP; BSFW).
	26 July	?	Many young chicks seen (BSFW).

Figure 16 Sooty Tern nesting area in the saddle between Flagpole and Annexation Hills. Looking toward Annexation Hill. Photograph by Derral Herbst, 28 August 1968.

Table 16. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1964	25-26 Sept.	4	Not breeding. Four birds flew over island in the evening (POBSP; BSFW).
1965	15 Mar.	50,000	80% with eggs, 20% with chicks overall; about 50% with young on the Northwest Cape and 15-20% with young elsewhere; *Ca.* three near-fledging young seen (POBSP; BSFW).
1966	10-11 Sept.	300	Present by day, more present at night. A few unfledged chicks observed (BSFW).
1967	10 Mar.	15,000	All stages from eggs to fledged young (POBSP; BSFW).
	15 Sept.	100	*Ca.* 100 adults flying about with a few immatures among them (BSFW).
1969	22 Mar.	16,600	About 75% on eggs which appeared to have been newly laid. No young noted (BSFW).
1971	14 Sept.	<100	Less than five adults seen. All others seen were immatures (BSFW).
1972	15 Sept.	?	(BSFW).
1973	30 July	several thousand	190 fully feathered young still present (BSFW).

*Only eastern part of island explored.

**Only about half of island seen during brief survey.

BLUE-GRAY NODDY *Procelsterna cerulea*

Status

Common breeder (maximum recent estimate: 2,000 to 3,000). Present and breeding throughout the year but periods of peak breeding either non-existent or not yet established. Nests primarily in holes in cliffs and rocks.

Populations

Estimates (Table 17) are too few and too variable to draw any valid conclusions about changes in numbers from season to season or even to be certain about maximal numbers present. All that may be safely concluded is that the species is a common resident and that populations fluctuate considerably.

Annual Cycle

Various observations on breeding status are only complete enough to indicate that Necker Blue-gray Noddies have a very extended breeding season. Eggs were found during four of the months that the island has been surveyed (March, May, July, and September) and possibly in a fifth (December, 1953). Wetmore found only fledged young in June, suggesting that the breeding season had been completed but some recent September observations (1964, 1967) show that birds may be found breeding much later in the year.

Breeding Habitat

All observers reported or suggested that these birds nest over much of the island, and, in particular, on the steeper slopes and cliffs. Fisher (1903a: 781) reported that "The single egg is laid in a shallow bowl-like cavity or recess in the rock with no nest, but occasionally a few stray quills and rubbish scattered about." More recent observers frequently noted that they nested in holes in the cliffs; on at least two occasions (September 1966 and 1967) these noddies were considered more abundant on Northwest Cape than on the main part of the island.

Banding

Six adults were banded by the BSFW: three adults and a local in September 1964 and two adults in March 1965.

Specimens

Blue-gray Noddies were originally described from Necker Island as a new species (*Procelsterna saxatilis*) by Fisher (1903b). The species was since reduced to synonymy with *P. cerulea* but retained subspecific identity as *P. c. saxatilis*. Consequently, since Necker is the type locality, a large series of specimens has been collected by many observers.

In all, we have been able to find records of 35 specimens, most of them (29) now located in the National Museum of Natural History (USNM). Four specimens, the type, an adult male (USNM 188651), and three cotypes, an adult female, an immature female, and a juvenile male (USNM 188652-654), were collected by Fisher on 31 May 1902.

Four females and two males were subsequently collected by Bailey and Willett on 19 March 1913. Two of these, a male and a female, are located in the University of Michigan Museum of Zoology (UMMZ 121850-851) and the rest are located in the USNM (USNM 239016, 239996, 240015, 240017).

The largest series, consisting of eight males and 14 females, was collected by Wetmore on 19 June 1923. Twenty-one of these specimens (USNM 300363-367, 300369-382, 300448, 300449) are now located in the USNM but one (USNM 300362) was subsequently exchanged with the Paris Museum of Natural History.

Three additional specimens (BPBM 4853-4855) are located in the B.P. Bishop Museum, Honolulu, but we do not know when or by whom they were collected.

Table 17. Observations of Blue-gray Noddies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	fairly common	Eggs, all heavily incubated; downy young including one recently hatched, and juveniles (Fisher, 1903a: 777, 781-782).
1913	19 Mar.	common on cliffs	Only one egg found (Bailey, 1956: 32).
1916	27 Jan.	a few*	(Munter, ms.).
	11 Feb.	quite common**	Only eggs found (Munter, ms.).
1923	17-20 June	800	Apparently all young fledged (Wetmore, ms.).
1953	30 Dec.	4-8***	Apparently beginning to lay (Richardson, 1957: 25; and pers. comm.).
1962	11 June	?	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	Hundreds seen from offshore (POBSP; BSFW).
	26 July	200	Some nests with eggs found (BSFW).
	25-26 Sept.	450-500	From eggs to immatures present (POBSP; BSFW).
1965	15 Mar.	100^{+}	One nest with a fresh egg found (POBSP; BSFW).

Table 17. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1966	10-11 Sept.	?	No eggs or young found (BSFW).
1967	10 Mar.	2,000-3,000	Mostly eggs and small downy chicks; one chick about a week from fledging seen (POBSP; BSFW).
	15 Sept.	>254	254 counted. Population stated to be probably larger than this figure. One bird found incubating an egg (BSFW).
1969	22 Mar.	750	375 counted. Estimated based on other available but inaccessible nesting habitat. In most nests birds were incubating eggs (BSFW).
1971	14 Sept.	<50	No nests found (BSFW).
1973	30 July	40	(BSFW).

*Only westernmost peak of island examined.

**Only eastern part of island explored.

***Only about half of island seen during brief survey.

+Kridler considers that this estimate was low in view of observations made on subsequent visits.

BROWN NODDY *Anous stolidus*

Status

Abundant breeder (maximum recent estimate: 50,000). Probably present throughout the year but evidently much less common from about late December through at least late March. Breeding may occur in all months but in most years it apparently occurs principally between April or May and October or November. Nests on ground on open slopes.

Populations

Recent numerical estimates (Table 18) are usually somewhat larger than the estimate made by Wetmore in 1923, but not enough so that we

conclude that there has been any change in the size of the population. The very low numbers seen in December 1953 and on recent March visits indicate great variation in the numbers of birds present at different times of year.

Annual Cycle

Observations from three recent March visits (1965, 1967, 1969) indicate that few birds had returned to the island or begun to breed by early and mid-March, but observations from December 1953 and January and February 1916 indicate that breeding began earlier than March. Observations from July 1964 show that laying began by at least mid-May and suggest an egg peak in late June. The September 1964 observations and those from September 1966 indicate laying occurred into August or September and suggest a fledging peak about late September or early October. On the other hand, observations from September 1967 indicate that a larger proportion of the breeding population laid eggs in August and September that year than in 1964 and 1966. If, as the data suggest, there was a late August-early September laying peak in 1967, a fledging peak probably occurred in October and November.

The data available indicate that breeding can occur in *all* months but also suggest that the number breeding in some periods (December through March) is considerably reduced. On Necker this species evidently nests later in the year in larger numbers than on islands toward the northwestern end of the Hawaiian Chain (*e.g.*, Laysan and Lisianski Islands).

Breeding Habitat

Brown Noddies were found nesting in most areas on Necker but seemed to prefer open slopes. On three occasions (July 1964, September 1964 and 1966) Kridler noted that Brown Noddies nested in greatest abundance on Northwest Cape. Conversely, in September 1967 more than twice as many nests were seen on the main part of the island as on Northwest Cape.

No observer reported this species nesting in bushes and only Fisher (1903a: 783) described the nest. He reported that "the nest was smaller than on Laysan, the material being restricted from necessity to the fleshy stems of *Portulaca lutea*, which grows abundantly on the shelves of the rocks."

Banding

The POBSP banded 97 Brown Noddy chicks in September 1964. One of these (USFW band number 793-29149) banded 25 September 1964, not 24 September 1965 as reported by Amerson (1971: 381), was recaptured as an adult at Trig Island, French Frigate Shoals, on 8 June 1967 by POBSP personnel.

231-338 O - 77 - 6

Specimens

We know of two specimens from Necker, both adult females, collected by Wetmore on 18 and 19 June 1923 (USNM 300520, 300501).

Table 18. Observations of Brown Noddies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	fairly common	Nests and eggs (Fisher, 1903a: 783).
1913	19 Mar.	fairly common	Nesting (Bailey, 1956: 32; Willett, ms.).
1916	27 Jan.	very numerous*	Only eggs present (Munter, ms.).
	11 Feb.	quite common**	Only eggs found (Munter, ms.).
1923	17-20 June	6,000	Eggs found (Wetmore, ms.).
1953	20 Dec.	100-150***	A definite breeding season beginning (Richardson, 1957: 26; and pers. comm.).
1962	11 June	present	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	*Ca.* 10-25 seen from offshore (POBSP; BSFW).
	26 July	>20,000	At least 10,000 nests on the Northwest Cape. Most contained eggs but chicks in all stages of growth seen (BSFW).
	25-26 Sept.	8,000-10,000	Eggs to flying young. An estimated 3,000 chicks present (POBSP; BSFW).
1965	15 Mar.	*Ca.* 25	Only three birds actually seen. No evidence of breeding noted (POBSP; BSFW).
1966	10-11 Sept.	10,000	From eggs to fledged chicks. Only about one percent of breeding birds with eggs. An estimated 4,000+ young present. Chicks in all stages of growth seen but most 1/3 to 1/2 grown. Very few had fledged (BSFW).
1967	10 Mar.	0	None seen (POBSP; BSFW).

Table 18. (continued)

Date of Survey	Population Estimate	Breeding Status, Remarks and References
1967 15 Sept.	9,100	*Ca.* 2,200 nests with eggs; 950 with downy chicks counted and/or estimated. Notes state that these figures are less than actual totals present (BSFW).
1969 22 Mar.	25	No nests found (BSFW).
1971 14 Sept.	50,000	Most abundant bird on island. Nests contained eggs to full grown young (BSFW).
1973 30 July	11,000	Eggs and an estimated 800 young present Estimate possibly low (BSFW).

*Only westernmost peak examined.

**Only eastern part of the island explored.

***Only about half of island seen during survey.

BLACK NODDY *Anous tenuirostris*

Status

Common breeder (maximum recent estimate: 1,000). Present and has bred in all months, but probably does not breed in all months every year.

Populations

Recent estimates (Table 19) consistently indicate that only small numbers of Black Noddies occur on Necker. Maximal populations are evidently on the order of 1,000 birds but considerably fewer birds were recorded on visits when no active nests were found. The largest recent estimates are about three to five times as large as the single early estimate (June 1923) but we cannot be certain whether there has been any real increase in numbers.

Annual Cycle

Available data on breeding status indicate that breeding has occurred in all months but not necessarily in all months every year. No well-defined pattern of annual breeding can be deduced from the data.

Eggs have been laid in November or December (1953), January (1967), February (1965, probably 1967), June or July (1964), and August or September (1964). However, data from two of three September surveys suggest that breeding was largely completed by then. Clearly, more detailed data on breeding status are needed from many months to determine breeding peaks and the breeding schedule.

Breeding Habitat

Wetmore (ms.) noted that Black Noddies nested in clefts in the rocks in June 1923. Recent observers have found these birds nesting most commonly in small holes in the cliffs on Northwest Cape with smaller numbers nesting on steep, inaccessible slopes of the main part of the island. Others probably nest in the steep cliffs of the north side of the island.

Specimens

Apparently only three specimens have been collected. Wetmore collected two adult males (USNM 300446, 300459) on 19 June 1923 and an adult female (USNM 300460) on 20 June 1923.

Table 19. Observations of Black Noddies on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1902	31 May	?	No nests found (Fisher, 1903: 784).
1913	19 Mar.	fairly common	(Bailey, 1956: 32).
1923	17-20 June	200	Nesting (Wetmore, ms.).
1953	20 Dec.	400-500*	Eggs and young present (Richardson, 1957: 26; and pers. comm.).
1964	8 Mar.	?	*Ca*. 25-50 seen from offshore (POBSP; BSFW).
	26 July	600**	*Ca*. 300 nests found; all contained eggs (BSFW).
	25-26 Sept.	300-400	Eggs to flying young in seven nests found on the Northwest Cape (POBSP; BSFW).
1965	15 Mar.	250-300	Six of ten nests checked on Northwest Cape contained eggs, one a small downy chick (POBSP; BSFW).

Table 19. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1966	10-11 Sept.	20	No eggs or young noted (BSFW).
1967	10 Mar.	1,000	Some nests with eggs and at least one half-grown nestling seen on Northwest Cape (POBSP; BSFW).
	15 Sept.	150	Seen in one flock at the end of the Northwest Cape. No active nests found (BSFW).
1969	22 Mar.	500	About 80% of birds present on eggs (BSFW).
1971	14 Sept.	not too common	No nesting noted (BSFW).

*Only about half of island seen during brief survey.

**Estimate is only for the number of breeding birds present.

WHITE TERN *Gygis alba*

Status

Common breeder (maximum recent estimate: 600). Present and breeding throughout the year. Lays single egg in holes in rocks or on rock ledges, particularly on the steeper cliffs.

Populations

Numerical estimates (Table 20) indicate neither seasonal change in numbers nor that numbers have changed since 1923. This apparent lack of seasonal variation is quite different from that observed on other northwestern Hawaiian Islands such as Laysan and Lisianski. However, estimates may be less accurate than those obtained on Laysan and Lisianski, because Necker has much nesting habitat that is inaccessible and which is observed with difficulty, if at all. Few numerical estimates have been made in mid-summer or winter; it is possible that there are seasonal differences in size of populations which are not revealed by the available data.

Annual Cycle

Our data indicate that breeding may occur throughout the year and that eggs and young may be found in all months. Since proportions

of nests containing eggs and various sizes of young were almost never recorded, we cannot determine whether there is a regular, seasonal breeding peak. Data from the only survey where such information was recorded (September 1966) suggest a late summer breeding peak.

Breeding Habitat

All observers who mentioned nest sites agree that White Terns nested principally on the steep rocky cliffs of the island. Some have also been found nesting along the higher ridges (March 1967). On at least two surveys (March 1965, September 1966), this species was thought to be more abundant on the Northwest Cape than on the main part of the island.

Banding

In September 1964 the BSFW banded 31 White Terns (nine adults, two immatures, and 20 locals).

Specimens

Three specimens, all collected by Wetmore, are in the USNM. One (USNM 300390) is a juvenile female; the other two (USNM 300408, 300419) are adult males.

Table 20. Observations of White Terns on Necker Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1891	28 May	?	Seen offshore (Munro, 1941a: 2).
1902	31 May	one of the commonest terns	Eggs, a hatching young, and many small nestlings (Fisher, 1903a: 785).
1913	19 Mar.	abundant	Nesting (Bailey, 1956: 32).
1916	27 Jan.	a few*	(Munter, ms.).
	11 Feb.	a few**	None found nesting (Munter, ms.).
1923	17-20 June	800	Eggs and young present (Wetmore, ms.).
1953	20 Dec.	300-400***	Eggs and few newly fledged young seen (Richardson, 1957: 27; and pers. comm.).
1962	11 June	present	(Kramer and Beardsley, ms.).
1964	8 Mar.	?	Hundreds seen from offshore (POBSP; BSFW).

Table 20. (continued)

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1964	25 July	500-600	Eggs to nearly fledged young. An estimate of at least 50 nests in the vicinity of the top of Bow Hill (BSFW).
	25-26 Sept.	400-500	Eggs to immatures (POBSP; BSFW).
1965	15 Mar.	200	Nests with eggs found (POBSP; BSFW).
1966	10-11 Sept.	500-600	Eggs to fledged young seen. 75-80% of nests contained young (BSFW).
1967	10 Mar.	600	Eggs and small chicks present (POBSP; BSFW).
	15 Sept.	> 363	Count of 363 stated to be a minimum figure. A few seen on eggs. Both small downy young and large chicks also seen (BSFW).
1969	22 Mar.	500	150 birds counted. Estimate based on additional nesting habitat which could not be censused. Eggs to nearly fledged young (BSFW).
1971	14 Sept.	400-500	(BSFW).
1972	15 Sept.	?	(BSFW).
1973	30 July	200	An estimated 50 young present. Estimate almost certainly too low (BSFW).

*Only westernmost peak of island examined.

**Only eastern part of island explored.

***Only about half of island seen during survey.

MOCKINGBIRD *Mimus polyglottos*

Status

Vagrant; one September sight record.

Observations

Kridler and others saw a Mockingbird fly over the lower southeast slopes of Flagpole Hill on 15 September 1967. Although seen but briefly, and not observed subsequently that day, all relevant field characters were clearly seen.

This species has not been recorded previously from Necker but has been recorded at least three times previously in the northwestern Hawaiian Islands, all at French Frigate Shoals (Clapp and Woodward, 1968: 33; Amerson, 1971: 302). All these records were presumably of birds that wandered from resident populations in the main Hawaiian Islands.

Mammals

The only mammal ever recorded from Necker Island is the Hawaiian Monk Seal which occurs and breeds on most of the northwestern Hawaiian Islands.

HAWAIIAN MONK SEAL *Monachus schauinslandi*

Status

Regularly present in small numbers. Maximum count: 20.

Observations

Observations of seals at Necker (Table 21) suggest that the species has occurred there regularly for almost a century. While no pups have yet been recorded, the consistency with which animals have been seen there in recent years, as well as the observation of four pregnant females, suggest the possibility that the seal may breed there.

Table 21. Observations of Hawaiian Monk Seals at Necker Island

Date of Survey		Number Seen	Remarks and References
1886	late summer or early fall	a few	One or more killed for shark-bait (Farrell, 1928: 253).
1894	27-29 May	?	A few seals seen by annexation party (Emory, 1928: 56).
1964	26 July	6	Swimming in Shark Bay (BSFW).
	25-26 Sept.	12	Adults hauled out on rocky shelf 25 September: six females, sex of rest not determined (BSFW; POBSP).

Table 21. (continued)

Date of Survey		Number Seen	Remarks and References
1965	15 Mar.	7	Basking on Shark Bay side of shelf connecting the two parts of the island: six adults (two sexed were male and female), one subadult female (BSFW, POBSP).
1966	10-11 Sept.	6	In same locality as previous observation: four adults (two females, one male), two subadults; one female molting (BSFW).
1967	10 Mar.	12	Six adults (at least one male; two females), six yearlings (at least one male; one female) (BSFW).
	15 Sept.	15	Basking in same locality as above. Thirteen adults (two males, five females), one yearling male, one yearling female (BSFW).
1968	28-29 Aug.	?	Several seen (BSFW).
1969	22 Mar.	20	On Shark Bay side of junction between Northwest Cape and mainland: seven adult males, four pregnant females, three subadults (one male, two females), six not aged or sexed (BSFW).
1971	18 Aug.	10	Counted in Shark Bay (BSFW).
	14 Sept.	16	All adults. Twelve were on the flat shelf on the Shark Bay side of the cut separating Northwest Cape from the main island; the other four were on a ledge on Shark Bay below Summit Hill (BSFW).
1973	30 July	18	All adults (BSFW).

Reptiles

Only one species of reptile, a sea turtle, is known to occur at Necker. The inhospitable habitat and infrequency of landings on Necker presumably account for the absence of lizards, which are found on a number of the other northwestern Hawaiian Islands.

GREEN TURTLE *Chelonia mydas* [=*agassizi*]

Status

Regular visitor in small numbers. Maximum count: 6.

Observations

Recent observations of turtles at Necker (Table 22) suggest that the dearth of early records is probably more the result of lack of interest in recording their presence than the result of a lack of turtles. These turtles do not breed at Necker but the remarkable frequency with which they have been seen on recent visits suggests that the area offshore is a much used feeding area.

Tagging

BSFW personnel tagged ten turtles at Necker (Table 22). The tag return obtained by the BSFW also suggests that some turtles may remain for awhile in the vicinity before continuing their pelagic wandering or returning to their natal island, which, for most Necker turtles, is probably French Frigate Shoals.

Table 22. Observations of Green Turtles at Necker Island

Date of Survey		Number Seen	Remarks and References
1923	12-21 June	a few	Found hauled out on rock shelves (Wetmore *in* Mellen, 1925: 161).
1964	26 July	1	Seen near the island in Shark Bay (BSFW).
	25-26 Sept.	2	One *ca*. 35" and one *ca*. 18" (BSFW; POBSP).
1965	15 Mar.	5	*Ca*. 2.5-3' long; resting on low ledge on Shark Bay side of island (BSFW: POBSP).
1966	10-11 Sept.	6	Five noted, *ca*. 2.5-3' turtles seen (and tagged) on same ledge as above. Another *ca*. 3' seen subsequently in west cove (BSFW).
1967	10 Mar.	3	*Ca*. 3'; two tagged; in same location as above (BSFW; POBSP).
	15 Sept.	3	Same size and locality as above; two tagged, one a recovery of a turtle tagged the previous visit (BSFW).

Table 22. (continued)

Date of Survey	Number Seen	Remarks and References
1969 22 Mar.	4	In same area as above; one tagged (BSFW).
1971 21 Aug.	1	Seen swimming offshore (BSFW).
14 Sept.	3	Two large females and one smaller turtle were hauled up on the ledge on the Shark Bay side of the cut separating Northwest Cape from the main Island (BSFW).
1973 30 July	3	A dead turtle found on shelf adjacent to Shark Bay. Three other turtles observed at a depth of about 45 feet (BSFW).

ACKNOWLEDGMENTS

Field work on Necker Island was made possible by a co-operative agreement between the Department of the Interior, Bureau of Sport Fisheries and Wildlife, and the Smithsonian Institution. We are indebted to the U.S. Coast Guard whose logistic support made possible the visits to Necker.

Mr. Edwin H. Bryan, Jr., B.P. Bishop Museum, Honolulu, Hawaii, generously allowed us access to his reference files which were of particular value in our preparation of the history section of this report. We are also particularly indebted to Dr. Alexander Wetmore, Smithsonian Institution, Washington, D.C., who allowed us full use of his previously unpublished observations made during the Tanager expedition in 1923. We also thank Dr. Frank Richardson, University of Washington, Seattle, Washington, who communicated to us avian population estimates that he made during his visit to Necker in December 1953.

Dr. Philip S. Humphrey, University of Kansas, Lawrence, Kansas, principal investigator of the POBSP, offered constant encouragement which led to the completion of this manuscript. We also thank the POBSP and BSFW personnel, listed in Appendix Table 1, who did the field work on which the bulk of this report is based. Derral Herbst kindly wrote the vegetation section. A. Binion Amerson, Jr., and Phillip C. Shelton made many helpful comments during various stages of manuscript preparation and Dr. F. Raymond Fosberg was kind enough to read and criticize the vegetation section. We are also grateful to Tina C. Clapp who aided in the preparation of several of the figures. A. Binion Amerson, Jr., edited the final manuscript.

The camera copy was typed by Barbara B. Anderson with funding through a contract with the Bureau of Sport Fisheries and Wildlife, Department of the Interior (contract number 14-16-008-596, February 3, 1971).

LITERATURE CITED

Agassiz, A. and H.L. Clark. 1907-1912. Hawaiian and other Pacific Echini. Mus. Comp. Zool. Harvard, Mem. 34: vii and 383 p.

Aldrich, J.M. 1931. New Acalyptrate Diptera from the Pacific and Oriental Regions. Haw. Ent. Soc., Proc. 7(3): 395-399.

Alexander, W.B. *et al.* 1965. The families and genera of petrels and their names. Ibis 107: 401-405.

Alexander, W.D. 1894. Stone idols from Necker Island. J. Polynesian Soc. 3: 153-154.

Anonymous. 1894. Hawaiian Star. 31 May.

A.O.U. [American Ornithologists' Union]. 1957. Checklist of North American Birds. 5th ed. Lord Baltimore Press, Baltimore. xii and 691 p.

_____ Committee on Classification and Nomenclature. 1973. Thirty-second supplement to the American Ornithologists' Union check list of North American birds. Auk 90: 411-419.

Amerson, A.B., Jr. 1968. Tick distribution in the Central Pacific as influenced by seabird movement. J. Med. Ent. 5: 332-339.

_____ 1971. The Natural History of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Res. Bull. 150: 1-383.

_____ (ms.) French Frigate Shoals, a history: 1786-1970 [287 p. typescript in the files of the POBSP].

Bailey, A.M. 1956. Birds of Midway and Laysan Islands. Denver Mus. Nat. Hist., Mus. Pict. 12: 1-130.

Beardsley, J.W. 1966. Insects and other terrestrial arthropods from the Leeward Hawaiian Islands. Haw. Ent. Soc., Proc. 19(2): 157-185.

Berger, A.J. 1972. Hawaiian birdlife. Univ. of Hawaii Press, Honolulu. xii and 270 p.

Brooke, J.M. (ms.). Log of the USS FENIMORE COOPER. Rec. Group 37, U.S. Nat. Arch., Washington, D.C.

Brooks, N.C. 1860. Islands and reefs west-northwest of the Sandwich Islands. Pac. Naut. Mag. 29: 499-504.

Bryan, E.H., Jr. 1938. Necker--mystery island of Hawaii. Paradise of the Pacific 50: 21-22.

_____ 1942. American Polynesia and the Hawaiian Chain. Tongg Publ. Co., Honolulu. 253 p.

Bryan, E.H., Jr. *et al.* 1926. Insects of Hawaii, Johnston Island, and Wake Island. B.P. Bishop Mus., Bull. 31: 1-94.

Bryan, W.A. (ms.). Letter to H.W. Henshaw, 13 Nov. 1914. Rec. Group 22, U.S. Nat. Arch., Washington, D.C.

BSFW - Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Kailua, Hawaii [unpublished reports]:

Kridler, E. [1964a]. Hawaiian Islands National Wildlife Refuge... [survey] - July 25-27, 1964. 8 p.

_____ [1964b]. Hawaiian Islands National Wildlife Refuge... [survey] - September 16 through 27, 1964. 31 p.

_____ [1966]. Hawaiian Islands National Wildlife Refuge trip - September 8-28, 1966. 34 p.

_____ [1967a]. Refuge log book for 6 March - 1 April 1967. 39 p.

_____ [1967b]. [Partial report of] Hawaiian Islands National Wildlife Refuge...[survey]...September 10 through October 4, 1967. 14 p.

_____ [1969]. Hawaiian Islands National Wildlife Refuge spring trip. March 19-April 6, 1969. 32 p.

_____ [1971]. Hawaiian Islands National Wildlife Refuge Trip Report. September 2-17, 1971. 30 p.

_____ [1972]. Expedition Report - Hawaiian Islands National Wildlife Refuge - September 3-17, 1972. 28 p.

Olsen, D.L. [1969]. Hawaiian Islands National Wildlife Refuge field trip, May 28 - June 11, 1969. 18 p.

_____ [1971]. Expedition Report - Hawaiian Islands National Wildlife Refuge - Nihoa, Necker, French Frigate Shoals - August 16-26, 1971. 16 p.

_____ [1973]. Expedition Report - Hawaiian Islands National Wildlife Refuge - July 22 - August 1, 1973. 17 p.

Buck, P.H. 1953. Explorers of the Pacific. B.P. Bishop Mus., Spec. Publ. 43: 1-125.

Christophersen, E. and E.L. Caum. 1931. Vascular plants of the Leeward Islands, Hawaii. B.P. Bishop Mus., Bull. 81: 1-41.

Clapp, R.B. and P.W. Woodward. 1968. New records of birds from the Hawaiian Leeward Islands. U.S. Nat. Mus., Proc. 124(3640): 1-39.

Clark, A.H. 1949. Ophiuroidea of the Hawaiian Islands. B.P. Bishop Mus., Bull. 195: 133 p.

Diggs, J.T. (ms.). Report on the cruise of the USS HERMES among the islands of the Hawaiian Group, 1918. Rec. Group 45, U.S. Nat. Arch., Washington, D.C. 24 p.

Edmondson, C.H., W.K. Fisher, H.L. Clark, A.L. Treadwell and J.A. Cushman. 1925. Marine zoology of the tropical central Pacific. B.P. Bishop Mus., Bull. 27: ii and 148 p.

Elschner, C. 1915. The leeward islands of the Hawaiian Group. Honolulu Advertiser, Honolulu. 68 p.

Emory, K.P. 1928. Archaeology of Nihoa and Necker Islands. B.P. Bishop Mus., Bull. 53: 124 p.

Farrell, A. [ed.]. 1928. John Cameron's odyssey. The MacMillan Co., New York. 461 p.

Fisher, W.K. 1903a. Birds of Laysan and the Leeward Islands. U.S. Fish Comm., Bull. 23(3): 769-807.

_____ 1903b. A new *Procelsterna* from the Leeward Islands, Hawaiian Group. U.S. Nat. Mus., Proc. 26(1322): 559-563.

_____ 1906. The starfishes of the Hawaiian Islands. U.S. Fish Comm., Bull. 23(3): 987-1131.

_____ 1907. The holothurians of the Hawaiian Islands. U.S. Nat. Mus., Proc. 32(1555): 637-744.

Fowler, H.W. 1927. Fishes of the tropical central Pacific. B.P. Bishop Mus., Bull. 38: 1-32.

Fowler, H.W. and S.C. Ball. 1925. Fishes of Hawaii, Johnston Island and Wake Island. Tanager Expedition Publ. 2. B.P. Bishop Mus., Bull. 26: 1-31.

Frear, W.F. (ms.). Letter from Governor of Hawaii to the U.S. Secretary of the Interior, 30 April 1909. Rec. Group 126, U.S. Nat. Arch., Washington, D.C.

Great Britain Hydrographic Department, Admiralty. 1946. Pacific Islands Pilot, 7th ed., Vol. III. xxxiv and 342 p.

Gregory, H.E. 1924. Report of the Director for 1923. B.P. Bishop Mus., Bull. 10: 1-38.

_____ 1925. Report of the Director for 1924. B.P. Bishop Mus., Bull. 21: 1-55.

Hardwick, D.F. 1965. The corn earworm complex. Ent. Soc. Canada, Mem. 40: 1-247.

Hardy, D.E. 1964. Diptera: Brachycera II-Cyclorrapha I. *In* E.C. Zimmerman [Ed.]. Insects of Hawaii. Vol. 11. Univ. of Hawaii Press, Honolulu. vii and 458 p.

Herbst, D. (ms.). Flora and vegetation of Necker Island [8 p. typescript in the files of the POBSP].

Jacobs, W.V.E. (ms.). Report to the Secretary of the Treasury of investigation and apprehension of Japanese plumage hunters in January 1910. Rec. Group 26, U.S. Nat. Arch., Washington, D.C. 18 p.

Jehl, J.R., Jr. 1968. Relationships in the Charadrii (shorebirds): a taxonomic study based on color patterns of the downy young. San Diego Soc. of Nat. Hist., Mem. 3: 1-54.

Kellogg, V.L. and J.H. Paine. 1910. Mallophaga from the birds of Laysan Island. Ent. News 21: 124-125.

King, J.A. (ms.). Report to Hawaiian President Dole, 22 July 1895. State of Hawaii, State Archives, Honolulu.

King, P.N. (ms.). Hawaii's part in attempts to build a trans-Pacific cable 1893-1898. Thesis for M.A., 1965. History Dept., Univ. of Hawaii, Honolulu. 103 p.

King, W.B. 1967. Seabirds of the Tropical Pacific Ocean. Preliminary Smithsonian Identification Manual. Smithsonian Institution, Washington, D.C. xxxiii and 126 p.

Kramer, R.J. and J.W. Beardsley. (ms.). A report on a survey trip, and an entomological report, to Hawaiian Islands National Wildlife Refuge, June, 1962. Hawaii Dept. of Fish and Game, Honolulu. iii and 17 p.

La Pérouse, comte de, J.F. de G. 1799. Voyage of La Pérouse round the world...1785...1788...Translated from the French by L.A. Milet-Mureau. J. Robinson and J. Edwards and T. Payne, London. Vol. 1. 539 p.

Laycock, G. 1970. The Hawaiian Islands of birds. Aud. Mag. 72: 44-61.

Libby, W.F. 1954. Chicago radio-carbon dates, V. Science 120: 733-742.

Lopes, H. de Souza. 1938. On the genus *Goniophyto* Townsend 1927, with description of a new species from Hawaii. B.P. Bishop Mus., Occ. Pap. 14(10): 193-197.

Maa, T.C. 1972. Notes on the Hippoboscidae (Diptera), 1. Pac. Ins. 4: 583-614.

Magnusson, A.H. 1942. Lichens of Nihoa and Necker Islands. B.P. Bishop Mus., Occ. Pap. 17(2): 1-41.

Marshall, D.B. (ms.). Report of July 5, 1962 on inspection trip, Hawaiian Islands National Wildlife Refuge, June 6-26, 1962. Hawaii Dept. of Fish and Game, Honolulu. 9 p.

Mellen, I.M. 1925. Marine turtles asleep on Hawaiian sands. Zool. Soc. N.Y., Bull. 28: 160-161.

Möhle, F. 1902. Beitrag zur Petrographie der Sandwich- und Samoa-Inseln. Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie 15: 66-104.

Munro, G.C. 1941a. Birds of Hawaii...The White or Love Tern. Elepaio 1(10): 1-5.

_____ 1941b. Birds of Hawaii...An ocean cruise. Elepaio 2: 34-36.

Munter, W.H. (ms.). Report to the captain of the THETIS of bird observations made during a cruise to the Hawaiian Bird Reservation in January and February 1916. Rec. Group 26, U.S. Nat. Arch., Washington, D.C. 19 p.

Office of Geography, U.S. Dept. of the Interior. 1956. NIS [National Intelligence Survey] Gazetteer, Hawaiian Islands. Central Intelligence Agency, Washington, D.C. iii and 89 p.

Palmer, H.S. 1927. Geology of Kaula, Nihoa, Necker and Gardner Islands and French Frigate Shoals. B.P. Bishop Mus., Bull. 35: 1-35.

Paty, J. 1857. Account of the MANUOKAWAI--interesting account of her explorations. The Polynesian, 6 June 1857: 40.

Peters, J.L. 1931. Check-list of birds of the world. Vol. I. Harv. Univ. Press, Cambridge, Mass. xviii and 345 p.

_____ 1934. Check-list of birds of the world. Vol. II. Harv. Univ. Press, Cambridge, Mass. xvii and 401 p.

Pilsbry, H.A. 1927. Littoral barnacles of the Hawaiian Islands and Japan. Acad. Nat. Sci., Phila. Proc. 79: 308-317.

POBSP - Pacific Ocean Biological Survey Program, Smithsonian Institution [unpublished reports]:

Amerson, A.B., Jr. [1964]. Northwest Hawaiian Islands trip report, March 1964. 20 p.

231-338 O - 77 - 7

Fleet, R.R. [1964]. Leeward Islands Survey No. 5, September 1964. 10 p.

Banko, W. [1965]. Trip report---Hawaiian leeward islands survey ...March 11-23, 1965. 11 p.

Hackman, C.D. [1967]. Preliminary report of Leeward Island survey No. 18, March 6 to March 27, 1967. 12 p.

Powers, S. 1920. Notes on Hawaiian petrology. Am. J. Sci., 4th Ser., 50: 256-280.

Rathbun, M.J. 1906. The Brachyura and Macrura of the Hawaiian Islands. U.S. Fish Comm., Bull. for 1903, 23(3): 827-930.

Rice, D.W. and K.W. Kenyon. 1962. Breeding distribution, history and populations of north Pacific albatrosses. Auk 79: 365-386.

Richardson, F. 1957. The breeding cycles of Hawaiian seabirds. B.P. Bishop Mus., Bull. 218: 41 p.

Roach, F.L. (ms.). East Pacific Survey Phase I, USS DUVAL COUNTY LST 758 [typescript copy of report in the files of the 14th Naval District, Honolulu].

Rothschild, W. 1893-1900. The avifauna of Laysan and the neighboring islands. R.H. Porter, London. 3 pts., xx and xiv and 320 p.

Snyder, J.O. 1904. A catalogue of the shore fishes collected by the steamer ALBATROSS about the Hawaiian Islands in 1902. U.S. Fish Comm., Bull. 22: 513-538.

Strasberg, D.W. 1956. Notes on the blennioid fishes of Hawaii with descriptions of two new species. Pac. Sci. 10: 241-267.

Thomas, C. (ms.). Report of explorations made by the United States Fisheries Commission steamer ALBATROSS in and about the Hawaiian Islands during 1902. Rec. Group 22, U.S. Nat. Arch., Washington, D.C. 136 p.

Tomich, P.Q. 1969. Mammals in Hawaii. A synopsis and notational bibliography B.P. Bishop Mus., Spec. Publ. 57: 238 p.

Trempe, A.D. (ms.). Report on the bird life observed on the cruise of the RELIANCE in March 1936. Rec. Group 26, U.S. Nat. Arch., Washington, D.C. 5 p.

Tsuda, R.T. 1966. Marine benthic algae from the leeward Hawaiian group. Atoll Res. Bull. 115: 1-13.

Tucker, R.L. (ms.). Trip of the motor vessel "J.A. CUMMINS" from Honolulu to French Frigate Shoal. B.P. Bishop Mus., Pamph. 414: 1-5.

Usinger, R.L. 1942. The genus *Nysius* and its allies in the Hawaiian Islands. (Hemiptera, Lygaeidae, Orsellini). B.P. Bishop Mus., Bull. 173: 1-167.

Washington, H.S. and M.G. Keyes. 1926. Petrology of the Hawaiian Islands: V. The Leeward Islands. Am. J. Sci., 5th Ser., 12: 336-352.

Wetmore, A. (ms.). Field notes taken on 1923 Tanager Expedition (original in the possession of A. Wetmore).

Wilkes, C. 1845. Narrative of the United States Exploring Expedition, 5 vols. Lea and Blanchard, Philadelphia. Vol. 5. xv and 591 p.

Willett, G. (ms.). [Extracts from a report made to the Bureau of Biological Survey]. Bureau of Sport Fisheries and Wildlife, Kailua, Hawaii.

Woodward, P.W. 1972. The Natural History of Kure Atoll, Northwestern Hawaiian Islands. Atoll Res. Bull. 164: xii and 318 p.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 2. Apterygota to Thysanoptera. Univ. of Hawaii Press, Honolulu. viii and 475 p.

_____ 1948b. Insects of Hawaii. Vol. 3. Heteroptera. Univ. of Hawaii Press, Honolulu. v and 255 p.

_____ 1958a. Insects of Hawaii. Vol. 7. Macrolepidoptera. Univ. of Hawaii Press, Honolulu. ix and 542 p.

_____ 1958b. Insects of Hawaii. Vol. 8. Lepidoptera: Pyraloidea. Univ. of Hawaii Press, Honolulu. ix and 456 p.

Appendix Table 1. Scientific visits to Necker Island, 1891-1973

Date		Personnel	Vessel
1891	28 May	Rothschild Expedition* Henry C. Palmer George C. Munro	KAALOKAI
1894	27 May	Capt. James A. King Capt. William K. Freeman 1st Off. James Gregory Eng. Benjamin H. Norton Eight Hawaiian sailors	IWALANI
	24 Sept.	Members of the crew	CHAMPION
1895	12 July	James A. King William D. Alexander William T. Brigham (BPBM) Frank Dodge	LEHUA
1902	31 May	Albatross Expedition Charles H. Gilbert (SU) Walter K. Fisher (SU) Charles C. Nutting (SUI) John O. Snyder (SU)	ALBATROSS
1913	19 Mar.	A.M. Bailey (BBS)* George Willett (BBS)	THETIS
1914	8 Sept.	Carl Elschner Members of the crew	THETIS
1916	27 Jan.,	William H. Munter (CG) Members of the crew	THETIS
	11 Feb.	William H. Munter (CG) Members of the crew	
1918	3 Sept.	Members of the crew*	HERMES
1919	6 Oct.	Gerrit P. Wilder	KUKUI
1923	12-17, 21,29 June	Tanager Expedition Alexander Wetmore (BBS) (ornithologist) William G. Anderson (collector) A.L.C. Atkinson (HBAF) Edwin H. Bryan, Jr. (BPBM) (entomologist) Bruce Cartwright (BPBM) (assistant in hydrographic work)	TANAGER

Appendix Table 1. (continued)

Date	Personnel	Vessel
	Tanager Expedition (cont.) Chapman Grant (BBS) (naturalist) Charles S. Judd (forester) Edward L. Caum (BPBM) (botanist) Harold S. Palmer (BPBM) (geologist) Eric L. Schlemmer (assistant to Wetmore) David L. Thaanum (BPBM) (conchologist)	
1924 15-18 July	Tanager Expedition Harold S. Palmer (BPBM) (geologist) William G. Anderson (collector) William Bush (collector) Erling Christophersen (BPBM) (botanist) Theodore T. Dranga (BPBM) (conchologist) Kenneth P. Emory (BPBM) (ethnologist) Kenneth I. Hobson (collector) A. Landgraf (topologist)	TANAGER
1953 20 Dec.	Frank Richardson (UW)	BUTTONWOOD
1957 28 Dec.	Karl W. Kenyon (BSFW) Dale W. Rice (BSFW)	Aerial Survey
1962 11 June** (0630-0900)	Raymond J. Kramer (HDFG) David H. Woodside (HDFG) David B. Marshall (BSFW) John W. Beardsley (HSPA)	STONE COUNTY
1964 8 Mar.	Eugene Kridler (BSFW) A. Binion Amerson, Jr. (POBSP) Loren Kroenke (UH) Edward O'Neill (BSFW) Ronald L. Walker (HDFG) George S. Wislocki (POBSP)	PLANETREE

Appendix Table 1. (continued)

Date		Personnel	Vessel
1964	26 July (0900-1845)	Eugene Kridler (BSFW)	CHARLES H. GILBERT
	25-26 Sept. (0830-1300)	Eugene Kridler (BSFW) John W. Beardsley (UH) Robert R. Fleet (POBSP) Charles R. Long (POBSP) Ronald L. Walker (HDFG)	BASSWOOD
1965	15 Mar. (0900-1800)	Eugene Kridler (BSFW) Winston Banko (POBSP) Chandler S. Robbins (BSFW) Ronald L. Walker (HDFG)	BLACKHAW
1966	10-11 Sept. (0700-1520)	Eugene Kridler (BSFW) Sherwin Carlquist (CC) Karl W. Kenyon (BSFW) Warren Roll (HSB) Ronald L. Walker (HDFG)	IRONWOOD
1967	10 Mar. (1040-1715)	Eugene Kridler (BSFW) C. Douglas Hackman (POBSP) Ernest Kosaka (HDFG) John Maciolek (BSFW) Richard Wass (UH)	BUTTONWOOD
	15 Sept. (0910-1840)	Eugene Kridler (BSFW) Robert Ballou (BSFW) John L. Sincock (BSFW) Ronald L. Walker (HDFG)	BUTTONWOOD
1968	28-29 Aug. (0830-1845)	Eugene Kridler (BSFW) G. Brent Dalyrymple (CGS) Richard R. Doell (CGS) Robert Eddinger (UH) Derral Herbst (UH) John L. Sincock (BSFW)	BUTTONWOOD
1969	22 Mar. (0900-1740)	Eugene Kridler (BSFW) Karl W. Kenyon (BSFW) George Laycock (NAS) David L. Olsen (BSFW) John L. Sincock (BSFW)	BUTTONWOOD
	30 May (0900-1200)	David L. Olsen (BSFW)	MAHI

Appendix Table 1. (continued)

Date		Personnel	Vessel
1971	21 Aug. (1230-1500)	David L. Olsen (BSFW) David Childs (SI) Richard Grigg (HIMB) Robert J. Shallenberger (OI) James Vansant (UH) William Worcester (UH)	TERITU
	14 Sept. (0900-1500)	Eugene Kridler (BSFW) Erwin A. Bauer Kenneth S. Norris (OI) John L. Sincock (BSFW)	BUTTONWOOD
1972	15 Sept. (1000-1500)	Eugene Kridler (BSFW) Bruce Benson (HA) Ernest Kosaka (HDFG) David L. Olsen (BSFW) John L. Sincock (BSFW)	BUTTONWOOD
1973	30 July (1100-1830)	David L. Olsen (BSFW) John L. Sincock (BSFW) Leighton Taylor (BSFW) Thomas Telfer (HDFG)	BUTTONWOOD

---

*No landing made on island.

**Times of arrival and departure, where known, are listed under the dates of visit for surveys made during the 1960's and 1970's.

Glossary of Abbreviations:

BBS	Bureau of Biological Survey
BPBM	Bernice P. Bishop Museum
BSFW	United States Bureau of Sport Fisheries and Wildlife
CC	Claremont College, Claremont, California
CG	United States Coast Guard
CGS	United States Coast and Geodetic Survey
HA	Honolulu Adviser
HBAF	Hawaiian Board of Agriculture and Forestry
HDFG	Hawaii Division of Fish and Game
HIMB	Hawaii Institute of Marine Biology
HSB	Honolulu Star Bulletin
HSPA	Hawaiian Sugar Planters Association
NAS	National Audubon Society
OI	Oceanic Institute, Waimanalo, Hawaii
POBSP	Pacific Ocean Biological Survey Program

Appendix Table 1. (continued)

SI	Smithsonian Institution
SU	Stanford University
SUI	State University of Iowa
UH	University of Hawaii
UW	University of Washington

Appendix Table 2. Results of scientific visits to Necker Island, 1891-1973

Date		Results
1891	28 May	Bird observations made from offshore (Munro, 1941a,b).
1894	27 May	Hawaiian domain proclaimed and documents left on island. Seven stone images and a stone bowl collected.
	24 Sept.	Four images collected.
1895	12 July	Topographic survey made by Frank Dodge, and a number of specimens of birds and their eggs collected by W.T. Brigham.*
1902	30 May	Observations of birds (Fisher, 1903a), collection of plants. Blue-gray Noddy described as new species (Fisher, 1903b). Extensive offshore marine survey. Twenty bird specimens of five species collected.**
1913	19 Mar.	Observations on birds and their breeding status (Bailey, 1956). Eleven specimens of two species collected.**
1914	8 Sept.	Observations on geology and guano; map drawn.
1916	27 Jan.	Observations of birdlife.
	11 Feb.	Observations of birdlife.
1918	3 Sept.	Scanty observations of birds.
1919	6 Oct.	Image leg and a reshaped image collected.
1923 1924	12-21, 29 June 15-18 July	Ornithological observations (Wetmore, 1925);*** archaeological investigations; observations and collections of: vascular plants, crustacea, echinoderms, annelids, foraminifera, fish, chilopods, insects, molluscs, lichens and sponges. Geological and petrological observations and a topographic map made.

Appendix Table 2. (continued)

Date		Results
1923 1924	(cont.)	*Ca.* 58 bird specimens of 17 species collected; seven species of plants sowed by Judd.
1953	20 Dec.	Observations on birds and their breeding status (Richardson, 1957).
1957	28 Dec.	Aerial photographs taken to determine size of albatross populations (Rice and Kenyon, 1962).
1962	11 June	Brief notes on vegetation, birdlife, effects of military occupation of island; insects and arachnids collected.
1964	8 Mar.	Observations of birds made from offshore. Patrol of refuge.
	26 July	Observations of birds, turtles, seals; erection of refuge sign. Patrol of refuge.
	25-26 Sept.	Observations of birds, census of turtles and seals. Collected: plants, crustacea (isopods), arachnids, and insects. 174 birds of six species banded.*** Patrol of refuge.
1965	15 Mar.	Survey of birdlife; censuses of turtles and seals; 153 birds of four species banded. Patrol of refuge.
1966	10-11 Sept.	Observations of birds; censuses of turtles and seals; five turtles tagged; refuge sign erected. Patrol of refuge.
1967	10 Mar.	Studies and censuses of vertebrates, vegetation and marine life; patrol of refuge; two turtles tagged.
	15 Sept.	Patrol of refuge; observations of birds; two turtles tagged.
1968	28-29 Aug.	Studies and censuses of vertebrates, vegetation and marine life. Botanical survey for purpose of studying *Portulaca*; rock samples collected for a study of their magnetic properties; refuge sign erected; patrol of refuge.
1969	22 Mar.	Studies and censuses of vertebrates, vegetation and marine life; cover map made of island vegetation; current meters established offshore; patrol of refuge.

Appendix Table 2. (continued)

Date		Results
	30 May	Marine investigations around island; retrieval of current meters. No observations made of wildlife as only one observer landed on the island for a very brief period.
1971	21 Aug.	Coralline algae collected. Seals and turtles censused. No observations made of birds. Patrol of refuge.
	14 Sept.	Studies and censuses of vertebrates, vegetation and marine life; patrol of refuge.
1972	15 Sept.	Cursory observations of birds; seals censused; patrol of refuge.
1973	30 July	Studies and censuses of vertebrates, vegetation and marine life; patrol of refuge.

*Present location of these specimens unknown.

**We cannot be certain if this total is correct since the original papers reporting the visit did not report all collections.

***A new bird distributional record from this trip was reported by Clapp and Woodward (1968).

Appendix Table 3. Publications on collections and studies (with the exception of birds) made on Necker Island, 1891-1973*

	Protozoa
Cushman *in* Edmondson *et al.*, 1925	Records 27 species of foraminifera from offshore.
	Mollusca
Pilsbry, 1927	Reports two species of barnacles collected by the Tanager Expedition
	Annelida
Treadwell *in* Edmondson *et al.*, 1925	Reports a polychaete collected by the Tanager Expedition

Appendix Table 3. (continued)

Arthropoda

Arachnomorpha (Arachnida)	
Bryan *et al.*, 1926	Mentions occurrence of spiders and bird ticks.
Beardsley, 1966	Records four species of Araneida and one of Acarina from collections made in June 1962 and September 1964.
Amerson, 1968	Reports the distribution of hosts of ticks from collections made by the POBSP.
Crustacea	
Rathbun, 1906	Reports two species of brachyuran crabs collected at Necker and offshore by the Albatross Expedition.
Edmondson *in* Edmondson *et al.*, 1925	Reports nine species of decapods collected by the Tanager Expedition.
Bryan *et al.*, 1926	Mentions that isopods were collected.
Beardsley, 1966	Reports one isopod from a collection made in September 1964.
Labiata	
Myriapoda	
Bryan *et al.*, 1926	Describes a new species of Chilopoda from collections made by the Tanager Expedition.
Hexapoda - Insecta	
Kellogg and Paine, 1910	Reports one species of mallophaga collected by the Albatross Expedition.
Bryan *et al.*, 1926	Reports *ca.* 39 species of insects collected by the Tanager Expedition.
Aldrich, 1931	Describes a new ephydrid fly from specimens collected by the Tanager Expedition.

Appendix Table 3. (continued)

Hexapoda - Insecta (cont.)	
Lopes, 1938	Describes a new species of sarcophagid fly from material collected by the 1923 Tanager Expedition.
Usinger, 1942	Describes two new species of *Nysius* (Hemiptera, Lygaeidae) from specimens collected by the Tanager Expedition.
Zimmerman,** 1948a	Lists six species (one thysanuran, a cockroach, an embiompteran, an earwig, and two mallophaga).
Zimmerman, 1948b	Lists two species of Hemiptera (Lygaeidae).
Zimmerman, 1958a	Lists a noctuid moth and a lycaenid butterfly.
Zimmerman, 1958b	Lists a pyralid moth.
Hardy, 1964	Lists a dolichopodid fly.
Hardwick, 1965	Describes a noctuid moth from collections made by the Tanager Expedition.
Maa, 1962	Reports specimens of hippoboscid collected by the Tanager Expedition.
Beardsley, 1966	Records 28 new records from collections made in June 1962 and September 1964, and summarizes earlier records excluding Mallophaga.
Echinodermata	
Fisher, 1906	Reports one species of starfish (Asteroidea) collected by the Albatross Expedition.
Fisher, 1907	Reports four species of sea cucumbers (Holothuroidea) collected by the Albatross Expedition.
Agassiz and Clark, 1907-1912	Reports five species of Echinoidea collected by the Albatross Expedition.

Appendix Table 3. (continued)

Echinodermata (cont.)

Clark *in* Edmondson *et al.*, 1925	Reports two species of Ophiuroidea, three species of Echinoidea, and two species of Holothuroidea collected by the Tanager Expedition.
Clark, 1949	Summarizes records of echinoderms.

Chordata

Vertebrata

Pisces

Snyder, 1904	Reports five species of fishes collected by the Albatross Expedition; most had been carried to the island by birds.
Fowler and Ball, 1925	Reports 17 species collected by the Tanager Expedition.
Fowler, 1927	Lists two species collected by the Tanager Expedition and previously reported in Fowler, 1925.
Strasberg, 1956	Revises taxonomy of Hawaiian blennioid fishes, recording one species from Necker.

Reptilia

Mellen, 1925	Reports that Green Turtles were found by the Tanager Expedition in 1923.
Emory, 1928	Erroneously stated that "Turtles... abound."

Mammalia

Emory, 1928	States that "The Hawaiian seal has been shot on Necker."
Farrell, 1928	Reports that seals were seen at Necker in 1886.
Tomich, 1969	Reports occurrence of monk seal in March 1965.
Laycock, 1970	Mentions occurrence of monk seals in March 1969.

Appendix Table 3. (continued)

	Flora
Fisher, 1903a	Reports three species of vascular plants collected by the Albatross Expedition.
Christophersen and Caum, 1931	Reports five species of vascular plants collected by the Tanager Expedition and lists seven species planted in 1923 which were not present in 1924.
Magnusson, 1942	Lists eight species of lichens, six of which are newly described, from collections by the Tanager Expedition of 1924.
Tsuda, 1966	Reports collection of 17 species of marine benthic algae collected in July 1924 and September 1964.
	Geophysical
Möhle, 1902	Describes three specimens of lava.
Elschner, 1915	Gives comments on the geology and chemical composition of guano from observations made in September 1914.
Powers, 1920	Describes a specimen of lava collected in 1914.
Washington and Keyes, 1926	Reports results of studies of rocks collected by the Tanager Expedition.
Palmer, 1927	Gives geological and topographical observations made by the Tanager Expedition.
	Archaeology
Alexander, 1894	Gives a photograph of idols collected in 1894.
Emory, 1928	Reports work done by the Tanager Expedition and summarizes all available earlier information.

*Authors are in chronological order within taxa.

**Zimmerman and Hardy, in the Insects of Hawaii series, present distributional records derived primarily from the Tanager collections, but extensively revise taxonomy, re-identify specimens, and identify to species hitherto unidentified specimens.

ATOLL RESEARCH BULLETIN
NO. 207

THE NATURAL HISTORY OF NIHOA ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

by Roger B. Clapp, Eugene Kridler and Robert R. Fleet

Issued by
THE SMITHSONIAN INSTITUTION
with the assistance of
The United States Fish and Wildlife Service
U.S. Department of the Interior
Washington, D. C., U.S.A.

May 1977

TABLE OF CONTENTS

231-338 O - 77 - 8

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

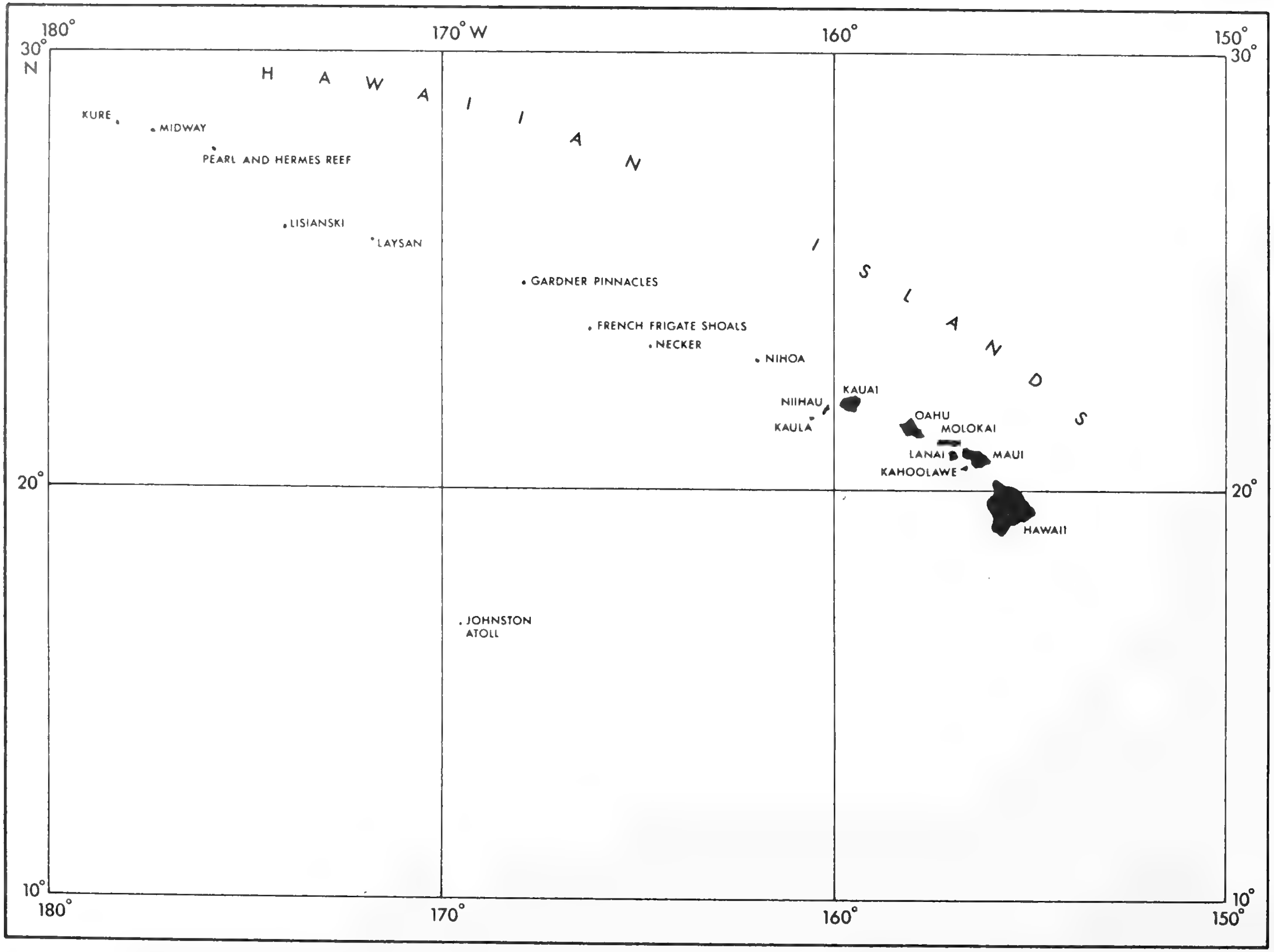


Figure 1 The Hawaiian Islands.

THE NATURAL HISTORY OF NIHOA ISLAND, NORTHWESTERN HAWAIIAN ISLANDS[1/]

by Roger B. Clapp[2/], Eugene Kridler[3/], and Robert R. Fleet[4/]

INTRODUCTION

Nihoa Island, sometimes known also as Bird Island, is a precipitous remnant of a volcanic peak and is the easternmost of a chain of islands comprising the Hawaiian Islands National Wildlife Refuge (Figure 1). Approximately 156 acres in extent, it lies at 23°06'N, 161°58'W (Off. of Geogr., 1956: 58), about 250 miles from Honolulu (Bryan, 1942: 167). Its nearest neighbor in the northwestern Hawaiian Islands is Necker Island lying about 155 miles to the west-north-west.

Few reports have been made about the biota of the island. Most of our knowledge of the bird life stems from a report by Vanderbilt and de Schauensee (1941) as well as from several papers dealing with the two endemic forms of passerines found on the island (Bryan, 1916, 1917; Wetmore, 1924, Richardson, 1954). A considerable amount of information was also obtained by the Tanager Expeditions of 1923 and 1924, but the material dealing with the birds was never published.

Beginning in 1964 the Pacific Ocean Biological Survey Program (hereafter POBSP) of the Smithsonian Institution and the Bureau of Sport Fisheries and Wildlife (hereafter BSFW) began making periodic surveys of Nihoa. From 1964 through 1973, 16 visits were made, together totaling 30.3 days of observation (Table 1 and Appendix Table 1). In the tables the unpublished survey material obtained by the BSFW and POBSP can be located through reference to the date of the survey. Dates are listed in the Literature Cited section under BSFW and POBSP.

1/ Paper Number 76, Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D.C.

2/ National Fish and Wildlife Laboratory, U.S. Fish and Wildlife Service, Department of the Interior, National Museum of Natural History, Washington, D.C. 20560.

3/ Office of Endangered Species and International Activities, U.S. Fish and Wildlife Service, Department of the Interior, 1311 Kapiolani Boulevard, Honolulu, Hawaii 96814.

4/ Department of Wildlife Sciences, College of Agriculture, Texas A & M University, College Station, Texas 77840.

Table 1. Recent surveys of Nihoa Island by the POBSP and BSFW*

Month	Year 1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Total Days of Observation
March	BSFW POBSP (1.1)	BSFW POBSP (1.2)		BSFW POBSP (1.0)	BSFW POBSP (2.0)	BSFW (0.3)					5.6
May-June						BSFW (12.4)					12.4
July	BSFW (0.4)									BSFW (0.3)	0.7
July-Aug.			BSFW POBSP (4.0)								4.0
August					BSFW (3.2)		BSFW (0.3)	BSFW (1.1)			4.6
Sept.	BSFW POBSP (1.3)			BSFW (1.2)				BSFW (0.2)	BSFW (0.3)		3.0
Total Days of Observation	2.8	1.2	4.0	2.2	5.2	12.7	0.3	1.3	0.3	0.3	30.3

*POBSP is listed under BSFW when POBSP personnel accompanied BSFW field parties on one of their regular inspection trips. Figures in parentheses are the approximate number of days spent on the island.

The primary purpose of this report, one of a series on the northwestern Hawaiian Islands, is to summarize present knowledge of the vertebrate fauna and vascular flora of Nihoa Island. A considerable effort has been made to thoroughly document previous information and many of these unpublished notes, particularly those of Dr. Alexander Wetmore, who led the 1923 Tanager Expedition, add considerably to our knowledge of the island's biota.

Secondarily, this report should serve as a reference to papers (see Appendix Tables 2 and 3) dealing with other aspects of the island's biota.

The present report was largely in final draft form in late 1970 and includes only slight emendations and additions after that period. The tables of observations have been emended to include BSFW information available through 1973 but only seldom has this additional information made changes in the text necessary.

BSFW and POBSP field notes and trip reports concerning Nihoa are, respectively, stored in the Bureau of Sport Fisheries and Wildlife files, Kailua, Oahu, Hawaii and the Pacific Ocean Biological Survey Program files, National Museum of Natural History, Washington, D.C.

DESCRIPTION

Nihoa, remnant of a volcanic cone, is characterized by steep slopes, rocky outcroppings, well developed valleys, and precipitous cliffs. Figures 2 and 3 present a vertical overview of this island which measures about 1,500 yards east to west and from 300 to 1,000 yards wide (Bryan, 1942: 167).

From the south the island present a distinct saddle-shaped appearance (Fig. 4) with the highest peaks being found on the northeastern and northwestern corners of the island. The maximum elevation of 895 feet is to the northwest at Miller's Peak (Fig. 5). In the vicinity of Miller's Peak are several acres of reasonably level land which is much favored by albatrosses for nesting. At the northeastern corner of the island is Tanager Peak (Fig. 6), its 852 foot elevation only slightly lower than that of the peak to the west. Between the peaks the elevation of the ridge drops to 360 feet near the head of Middle Valley (Fig. 7). This area often has small nesting concentrations of Blue-faced Boobies.

Cliffs dominate the perimeter of the island. The north, west, and east cliffs (Figs. 8-10) are nearly perpendicular to the surface of the ocean and at times may exhibit a small overhang. The cliffs of the western perimeter decline rather irregularly in height and in a few places rise to small peaks. The decline in height of the eastern cliffs is far more uniform. The cliffs of the south side are only 50 to 100 feet high and may be relatively easily scaled. Six valleys, varying considerably in the steepness of the slopes of the bordering ridges, fan out radially to the center or south of a point in Adam's Bay.

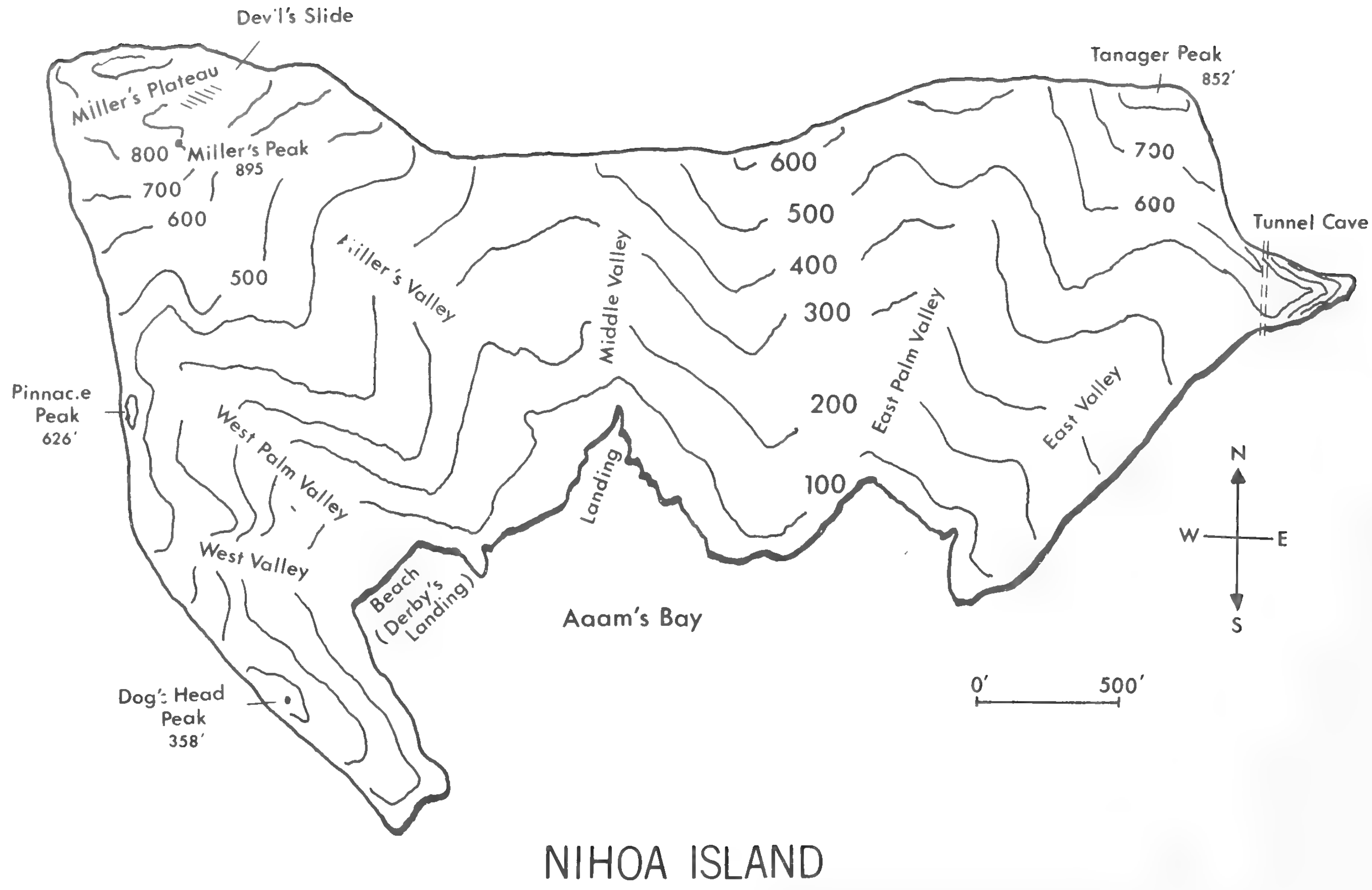


Figure 2. Map of Nihoa Island (after Christophersen and Caum, 1931: 5 and Bryan, 1942: 167).

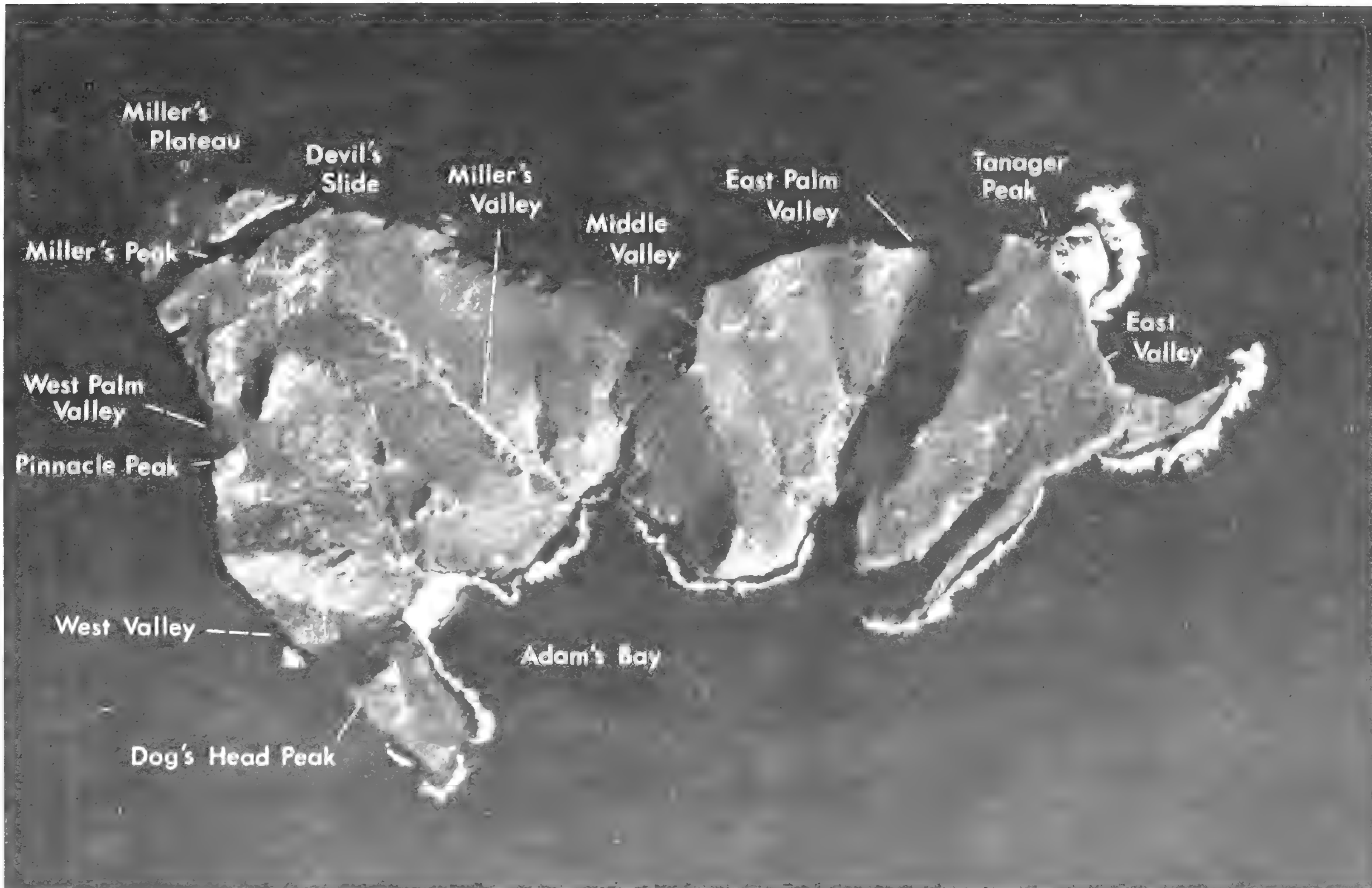


Figure 3. Aerial photograph of Nihoa Island showing prominent features of the island. Official U.S. Navy photograph, January, 1966.

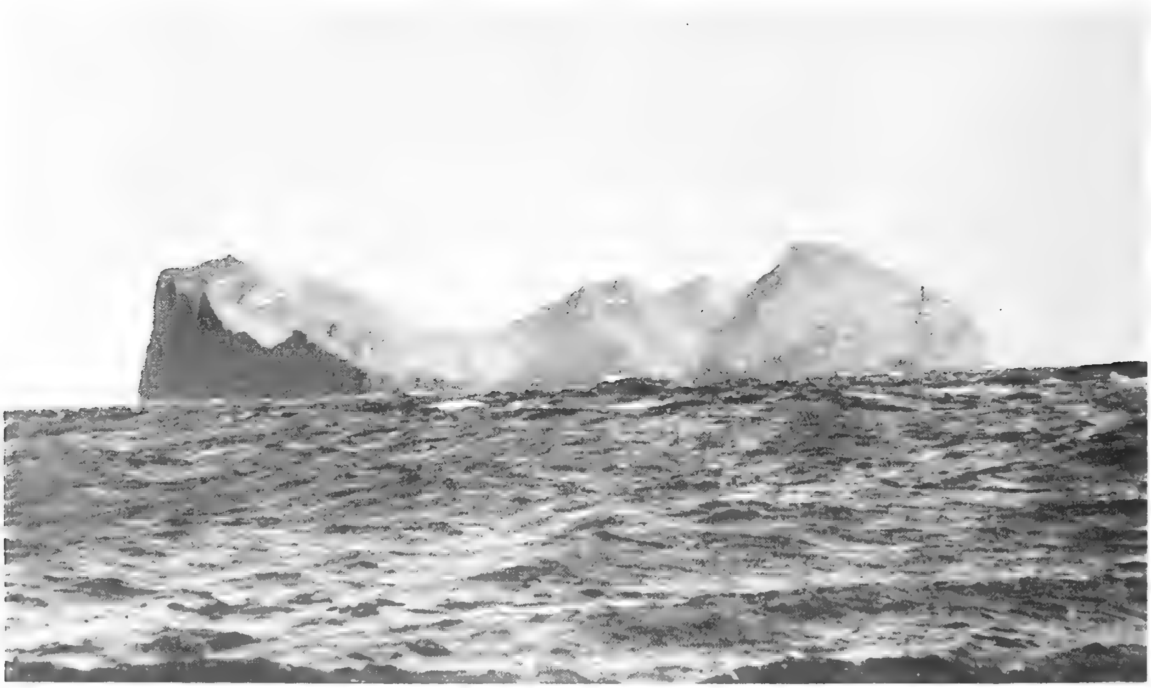


Figure 4. Looking at Nihoa Island from the south, December 1912. Photo courtesy of Virginia Frear Wild.

Figure 5. Viewing Miller Peak from the ridge west of Middle Valley. The dots in the right foreground are nesting Red-footed Boobies. POBSP photograph, 8 March 1968, by Roger B. Clapp.

Figure 6. Viewing Tanager Peak from the top of Middle Valley. Note dense *Chenopodium* on slopes and dry *Sida* in left foreground. POBSP photograph, 8 March 1968, by Roger B. Clapp

Figure 7. Low point along the north rim between Miller's and Tanager Peaks. POBSP photograph, 8 March 1968, by Roger B. Clapp.

Figure 8. Tanager Peak as seen from the air. Note steepness of north cliffs. BSFW photograph, July 1962, by David B. Marshall.

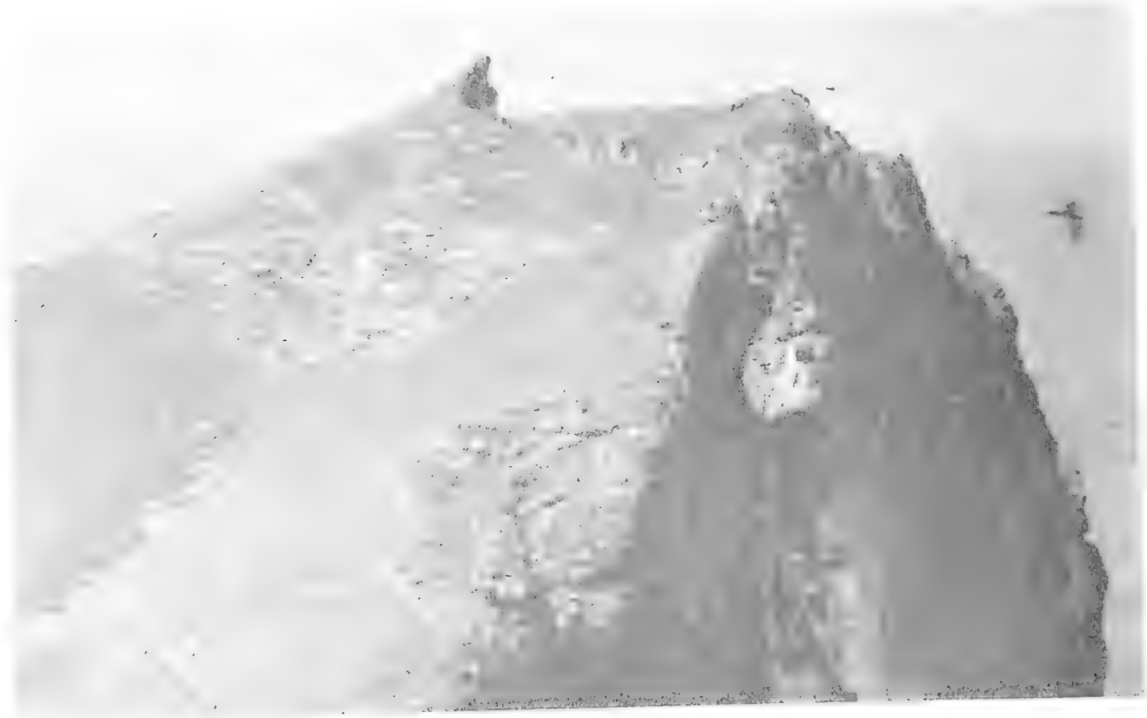


Figure 9. Miller's Peak as seen from the northeastern rim of the island, September 1964. BSFW photograph by Eugene Kridler.

The irregular southern perimeter of the island, enclosing Adam's Bay, is divided into three coves, the westernmost of which has a small sandy beach (Fig. 11) that is often called "Derby's Landing." It received its name in 1914 when a Lieutenant Derby swam ashore there to obtain some rock specimens for Carl Elschner (Bryan, 1942: 170). This is a poor landing spot because of the presence of submerged rocks.

The coves to the west are edged by rock terraces and the best landing spot is on the eastern side of the middle cove (Fig. 12). Nonetheless, if the weather is not favorable, landing here can be extremely hazardous.

The island is well vegetated but occasionally subject to drought which changes its green appearance to a sere yellowish-brown. Grasses tend to dominate the ridges with the valleys covered by dense scrub.

GEOLOGY

The earliest geologic observations of Nihoa were made by Sereno E. Bishop during a one day visit on 22 July 1885. His observations were of some value but were very brief and essentially similar to those made later and in greater detail by Palmer (1927).

Carl Elschner, aboard the USCG ship THETIS in 1914, was unable to land on the island but a Lieutenant Derby swam ashore and obtained some rock specimens. Elschner (1915) described the island in some detail but his observations were much improved upon by Harold S. Palmer.

Palmer, geologist on the Tanager Expedition, visited the island in 1923 and 1924 and later wrote the only detailed account of the geology of Nihoa (Palmer, 1927). Our brief account here, unless otherwise indicated, derives largely from his report.

Utilizing observations on the strike and dip of the dikes and of the positioning of the some 25 dikes cutting the west cliffs (Fig. 13), Palmer (1927: 11) concluded that

> ...Nihoa is a portion of the southwest quadrant of the original cone. This is further corroborated by the fact that Nihoa lies near the southwesterly end of a submarine bank with depths of 20 to 40 fathoms. [The U.S. Coast and Geodetic Survey Chart No. 4181 indicates that the bank has a depth of 25 to 35 fathoms and extends 13 nautical miles from Nihoa in a northwesterly direction.] The survival of a part of the southwest quadrant may be the result of protection from the attack of waves driven by the northeast trades. If no other action interfered, a homogenous [sic] island should be cut

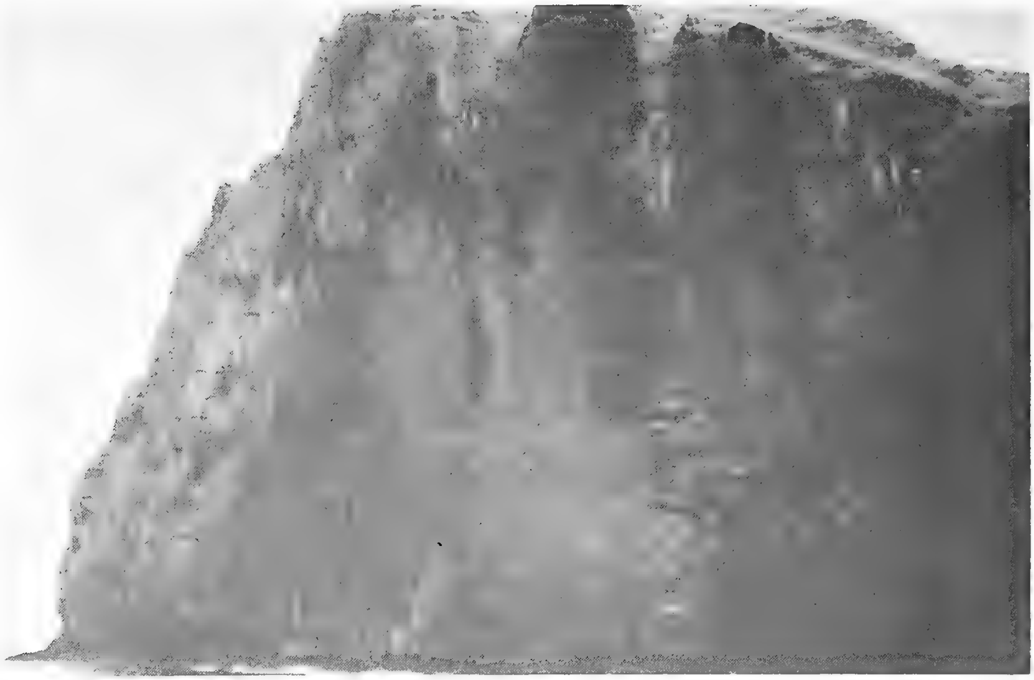


Figure 10. The steep west cliff of Nihoa Island. BSFW photograph, September 1971, by Eugene Kridler.

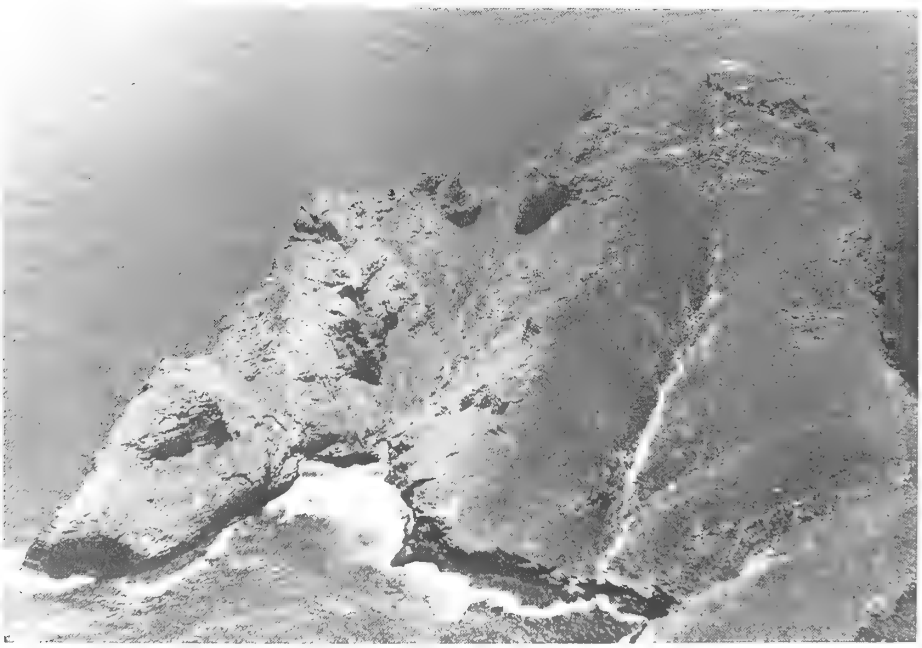


Figure 11. Western portion of island showing sandy beach in westernmost cove. Miller's Peak and Miller's Valley are to the right. In the center is Pinnacle Peak and West Palm Valley. To the extreme left is Dog's Head Peak. Just to the West of Dog's Head Peak is the small West Valley. BSFW photograph, June 1962, by David B. Marshall.

Figure 12. Best landing area is in the right foreground. Note the extent of rock terrace along the edge of the island. Camp is on a reasonably level spot near the base of Miller's Valley. POBSP photograph, 8 March 1968, by Roger B. Clapp.

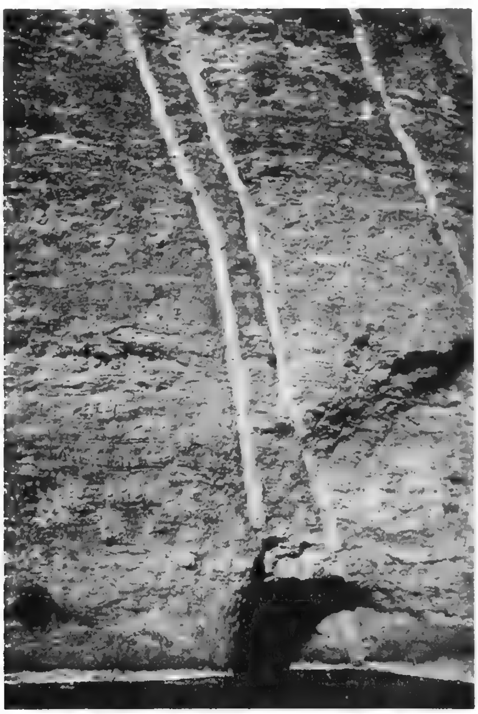


Figure 13. Three of the many dikes cutting the western cliffs. BSFW photograph, 15 September 1971, by Eugene Kridler.

> back most on its windward side both by wave attack and by stream erosion, and the last remnant should be a part of the original leeward quadrant.

Palmer noted that none of the original lava surface remained on Nihoa and stated that the flows were from 1 to 20 feet in thickness and exhibited considerable lateral extent.

Perpendicular or extremely steep cliffs are found on the east, west, and north sides of the island. Along the south shore cliffs are 50 to 100 feet high. These cliffs were caused by wave erosion which undermined higher layers of lava. Two other kinds of cliffs may be found on Nihoa. The more abundant type is found where massive, thick lava flows have resisted weathering and erosion more successfully than have adjacent flows, thus forming low cliffs. A third type of cliff is found where heavy dikes have protected the rock behind them while that in front was worn away. Palmer (1927: 13) described these as follows.

> In this way two great dikes northwest of the sand beach have formed a cliff 200 feet high, faced for nearly its full length by the dike material. The steep, chute like gash [the Devil's Slide, Fig. 14] which debouches through the north cliff near the northwest corner of the island has a steeply inclined floor and cliffs for side walls. The gash is due to the removal of the weaker flow lavas from the region between two dikes....A shallower chute on the west cliffs is due to the same processes working between the western extensions of the same dikes.

Nihoa has no permanent streams but Palmer thought that intermittent streams might be of considerable power, partly because of the scarcity of small boulders and gravel in the streamways and partly because the average slope of the island, excluding the cliffs, is about 23 degrees. Runoff is mostly to the south side of the island through the base of the valleys but the northwestern plateau drains mostly to the north. Palmer found three small seeps at the bottoms of streamways.

> [These seeps] represent ground water which is held up by relatively impervious layers of basalt, or which circulates through fissures in the basalt. The smallest seep is a little west of the head of the middle cove, and issues from crevices in the cliff behind the terrace. The second is at 270 feet elevation in the large valley to the east....The water here appears to be brought out by the overlying soil and rock by a massive and relatively impervious lava flow. The largest discharge of water is by seepage from the conglomerate body at the head of the west cove, and is brought to the surface in the same way. The water of all these seeps is heavily charged

> with acrid-tasting matter, presumably derived from the dejecta of the multitudinous birds and is nitrogenous and phosphatic in character (Palmer, 1927: 15).

Along the south shore lies a nearly continuous wave cut terrace, broken in three places, 4 to 8 feet above sea level and varying in width from 10 to 50 feet. Fragments of terrace also remain along other sides of the island.

At present wave action is cutting caves along the base of the north, northeast, southeast and particularly the west cliffs of the island. At the eastern end of the island a tunnel, through which small boats may pass, cuts through the 300 foot promontory (Palmer, op. cit.: 14).

Palmer found no slickensides, offset beds, or other signs of faulting.

The rocks of the island are mostly olivine basalts and occur either as dikes or flows. A few are olivine free basalts. No ash, bombs or tuff was found. Most of the rocks are medium gray except for a few which are dark brick red, due to oxide of iron. Oxidation is not restricted to the surface of the rocks and presumably occurred while the rock was still hot.

Olivine was found in at least 18 to 21 specimens examined by Palmer and occurred particularly commonly in the dike rocks. Feldspar (labradorite) phenocrysts were found in four sections. The ground mass of the rock consists primarily of elongated feldspar grains. Among the feldspar grains are augite grains, a few olivine grains and a little glass (Palmer, op. cit.: 16). Powers (1920) also briefly described a rock collected prior to the visits by the Tanager Expedition.

A detailed account of these rock specimens may be found in Washington and Keyes (1926). All the rocks examined by them were basaltic and occurred in four varieties: andesine basalt, olivine basalt, labradorite basalt and picrite basalt. In their chemical analysis of four specimens (one of each type of basalt) from 55 to 65 percent of the rocks consisted of SiO_2 and Al_2O_3 but appreciable quantities of FeO, MgO, and CaO were also present (Washington and Keyes, 1926: 344).

The rocks of Nihoa are of high specific gravity. Palmer weighed 11 specimens of dike rock and found specific gravities ranging from 2.53 to 3.06, with an average of 2.88. The varying abundance of olivine, a heavy mineral, accounts for the varying specific gravities.

Palmer also analyzed the sand from the beach in some detail. The principal components were grains of calcium carbonate, olivine and magnetite. Also found, but in much smaller amounts, were grains of feldspar, augite and lava. Details on the size of the grains,

their relative frequency of occurrence, and discussions of relative wear and appearance may be found by consulting Palmer.

Magnetite in the rocks of Nihoa causes wide variation in local magnetic declination. The average declination on Nihoa, like that of the surrounding ocean, is about 11 degrees E of N. However, declination at 10 points on Nihoa ranged from 2 to 28.5 degrees E of N, these two extremes coming from stations only 800 feet apart.

HISTORY

Prehistoric Habitation

Nihoa, like nearby Necker Island, was once inhabited by Polynesians. Emory (1928)[5/] reported that of the many stone structures (Fig. 15) at least 25 were foundations of houses and about 15 were ceremonial structures. Fifteen bluff shelters were discovered. He thought that the island could have sheltered a population of up to 174 persons but believed that probably no more than 100 ever lived there.

A large number of artifacts from terraces, house sites, and bluff shelters was collected by the Tanager Expedition. Artifacts of rock included grindstones, hammerstones, bowls, jars, and a mortar.

Artifacts of plant origin included a bed and a pillow made of bunchgrass, a wooden netting shuttle, a piece of breadfruit wood which had been shaped into a crude tiller of European form, and ashes and charcoal.

Artifacts of animal origin included a coral rubbing stone and file, awls or needles made of bird bones, fragments of turtle shells, and a fishhook of bone, probably from a human femur. Cowries (*Cypraea mauritiana*) had been used as squid lures.

Human skeletal material was found at two sites. At one, in a recess on the east side of Dog's Head, the remains of four adults were found with petrels nesting among the skulls. At the other, on a ledge facing the sea, were partial remains of an adult and two children.

After comparing the archaeological materials collected on Nihoa and Necker, *inter se*, and with those from other areas of Polynesia, Emory (1928) concludes that at one time Nihoa supported a permanent

---

5/ Emory (1928) gives an exhaustive account of the archaeology of Nihoa derived primarily from the results of the field work done by the Tanager Expeditions of 1923 and 1924.

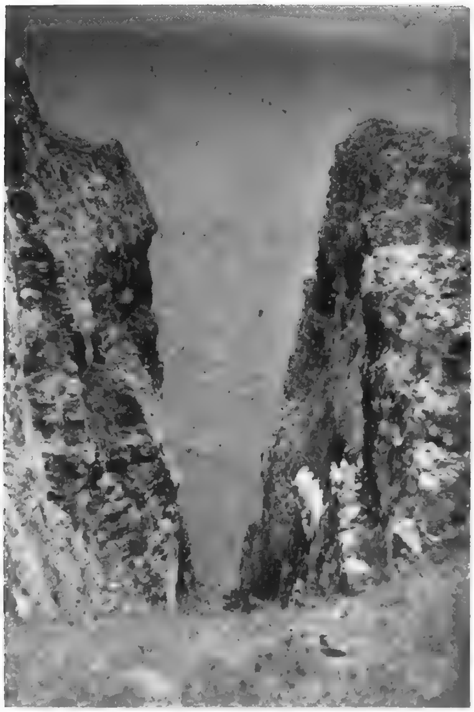


Figure 14. Looking north down the "Devil's Slide". BSFW photograph, 15 August 1970, by Eugene Kridler.

Figure 15. Native structure on the northeast corner of Miller's Plateau. BSFW photograph, 15 August 1970, by Eugene Kridler.

population which was part of the culture that also sprang up on Necker. He suggests that the permanent population of Nihoa arose when Nihoa was cut off from communication with the larger Hawaiian Islands.[6/] He hypothesizes that the people of the Necker culture were forced out of the main Hawaiians and settled for a time on Nihoa. Emory concludes that the Necker culture was "a pure sample of the culture prevailing in Hawaii before the thirteenth century, and that prehistoric as well as the historic Hawaiian culture may be considered Tahitian in origin" (Emory, 1928: 122).

European Discovery and Early Visits

Europeans discovered the existence of Nihoa when the island was sighted by Captain William Douglas of the H.M.S. IPHIGENIA. The IPHIGENIA, sailing in company with the schooner NORTH WEST AMERICA, sighted Nihoa at three in the morning of 19 March 1779 and hove to until daybreak. Meares (1790: 212), who evidently owned the ship,[7/] later reported that

> This island or rock, bears the form of a saddle, high at each end, and low in the middle. To the South it is covered with verdure; but on the North, West, and East sides, it is a barren rock, perpendicularly steep, and did not appear to be accessible but to the feathered race, with which it abounds. It was therefore named Bird Island.[8/] It lies in the latitude of 23 degrees 07' North, and in the longitude of 198 degrees 10' East [161 degrees 50' West], by a medium of several observed distances of the sun and the moon.

During ensuing years a number of ships passed offshore without making a landing: in March 1794 the British ships the DISCOVERY and the CHATHAM, and on 1 August 1795 the British sloop PROVIDENCE (Buck, 1953: 44, 46); on 17 April 1817 the bark COLUMBIA (Corney 1896: 73); and on 1 July 1825 the TARTAR (Morrell, 1841: 216).

In 1822, Queen Kaahumanu, having heard about Nihoa, sent two or three vessels commanded by Captain William Sumner to find the island

---

6/ Nihoa, but not Necker, was by tradition believed to have been known to the Hawaiians prior to the arrival of Europeans (Emory, 1928: 119).

7/ Buck, 1953: 38.

8/ A name by which Nihoa was best known through the first half of the 20th Century.

and annex it to the Hawaiian Kingdom (Thrum, 1893: 7; Emory, 1928: 8;9/ Bryan, 1942: 169). Adams, himself, states that he visited the island twice but never landed and further notes that "Kaahumanu visited the island in the Summer of 1822 and some of her natives landed on it...."10/

Another early landing was made by the crew of the U.S. Schooner DOLPHIN (Paulding, 1831: 192-195). Like many subsequent visitors they had considerable difficulty landing and returning from the island. Paulding's description follows.

> On the ninth of January, [1826] at eight in the morning...[Nihoa] was discovered close to us. We tacked and stood back close in with the southwest side, where was a small sand-beach, fifty to a hundred yards long.
>
> The captain, taking the Globe's whale-boat went in shore to fish, but seeing a few seal upon the sand beach was induced to land. It soon afterwards became squally and blew with great violence. The surf...rose with the wind, and,...the captain, after a short examination of the island...found it impossible to launch his boat...[and was forced to pass] the night on the island. It blew a gale and rained in torrents all night. The captain and his boat's crew took shelter in a cavern upon the seashore, where they had not been long by a comfortable fire they had made, when, by the rising of the tide the sea broke in upon them, and they with difficulty escaped to the side of the rocks, and thence upon the sand-beach. The island was high and almost perpendicular, and with the floods that fell and rushed down its steep sides, rocks of a large size were disengaged from their beds, and came tumbling down in every direction, to the great peril of the captain and his boat's crew....After a little search, they found an asylum in a cave at the side of the mountain, where they passed the night....

9/ Emory states also that Thrum's information about the 1822 visit was obtained from the journal of Captain Alexander Adams. This is impossible as the Adam's journal cited (Thrum, 1905: 66-74) covers only the period 16 January 1816 to 26 December 1817.

10/ Adams to L. Kamehameha, 18 March 1857. State of Hawaii, State Archives, Honolulu.

> [The following morning] When the captain saw the schooner approaching close in with the island, he made a last effort to launch his boat. They succeeded in getting her into the breakers but the first heavy roller that broke under them severed the boat amid-ships, and the captain upon end of her and a man that could not swim on the other, were hove up safely on the beach by the succeeding wave. The rest of the boat's crew were good swimmers and also landed in safety. Our boat was not far off when this occurred, and anchoring as near as possible to the shore, the men, all but one, swam off to her through the surf. The only way we could devise to get the captain and seaman off, was to float a cork-jacket on shore, at the end of a line, which being put on by the captain and seaman, afternately, and a rope tied around them, they were hauled through the surf without any other injury than swallowing a quantity of salt-water.
>
> Bird's Island is an uninhabited rock, about a league in circumference, and the highest part from five to eight hundred feet above the ocean. Where our boat landed, is the only spot where a landing could be effected, and upon that side alone it has an inclination by which it may be ascended. Every where else it is perpendicular, and at a distance, looks like the work of art. It has a scanty vegetation.

In the late 1850's many of the central Pacific islands became objects of commercial interest because of guano which was treated to make fertilizer. Most interest centered on the dry equatorial islands, many of which had substantial deposits, but the strong demand for guano and the potential for quick profits resulted in almost all central Pacific islands being investigated.

In December 1856 the Brisith warship HAVANA sailed from Honolulu to determine whether guano deposits were present on Nihoa. The ship arrived offshore on the morning of the eighth and remained offshore through the eleventh, but heavy seas prevented a landing. Captain Harvey went as close to shore as he dared but saw no guano, concluding that "from the formation of the rock and the large amount of heavy rain that falls in...[the island's] vicinity, I do not imagine it possible that any quantity could accumulate; --nor were birds seen in such quantities as to warrant the expectation" (Harvey, 1860: 423).

This expedition by a foreign ship in Hawaiian territory evidently alarmed the Hawaiian government, for shortly thereafter a

circular appeared claiming Hawaiian dominion over Nihoa.[11/]

The following spring an expedition was dispatched to Nihoa to annex formally the island to the Hawaiian Kingdom.

On 23 April 1857 Captain John Paty of the schooner MANUKAWAI, with King Kamehameha IV on board, landed and again annexed the island to the Hawaiian Kingdom. Paty's log describes the visit.

> At 10 a.m. went ashore (got upset in landing). The King and Governor landed at the same time in a canoe....
>
> I deposited a bottle at the foot of the pole near the landing place, containing notes agreeable to my instructions...also a plate of copper on which I scratched 23rd April A.D. 1857. King Kamehameha IV visited this Island, and took Possession.
>
> Not seeing anything to warrant my longer stay here, I got under way at 3 p.m. (Paty, 1857).

The EURYDICE, a French man-of-war, visited Nihoa at the same time and returned to Honolulu with the King and his party on board.

One of the primary purposes of the visit was to determine whether guano was present in sufficient quantity and quality for profitable mining. To Kamehameha's disappointment, Wm. Hillebrand, who analysed the samples brought back, concluded that the material was not valuable enough for shipping and export but that it might be of some use as a fertilizer in areas of the main Hawaiian Islands.[12/]

On 30 December 1858, Nihoa was viewed offshore by Lt. J.N. Brooke of the U.S. Schooner FENIMORE COOPER while en route to French Frigate Shoals.[13/]

In the early morning of 22 July 1885 an excursion party of over 200 people, including Princess Liliuokalani, landed on Nihoa from the steamer IWALANI. Others in the party included Sereno E. Bishop

---

11/ D.L. Gregg to the U.S. Secretary of State, 17, 24 December 1856. State of Hawaii, State Archives, Honolulu.

12/ Report from W. Hillebrand to L. Kamehameha, Minister of the Interior, 26 August 1856. State of Hawaii, State Archives, Honolulu.

13/ Log of the U.S. Schooner FENIMORE COOPER. Rec. Group 37, U.S. Nat. Archives, Washington.

and his assistants who made topographic and geological observations, Sanford B. Dole, who made ornithological observations, Mr. Jaeger, a botanist, and Mrs. E.M. Beckley, representative of the Hawaiian Government Museum (Emory, 1928: 10). Mr. Williams[14/] and W.E.H. Deverill took photographs and the latter collected several archaeological specimens.

Bishop's statement that "the island had been ransacked for birds, skins, eggs, and feathers" (Bishop, 1885b: 5) suggests that quite a number of ornithological specimens were collected but the present whereabouts of these specimens is unknown. Possibly most were lost, as were most photographs and the cameras, when two boats swamped during the departure of the excursion party.

Toward the end of the visit a fire had broken out that evidently consumed much of the island's vegetation (Bishop, 1885a: 4).

The schooner KAALOKAI carrying the Rothschild Expedition was off Nihoa on 26 and 27 May 1891. No landing could be made because of heavy seas, but expedition personnel Henry C. Palmer and George C. Munro made observations of birdlife offshore. Seventeen different species were seen (Palmer *in* Rothschild, 1893-1900: vii; Munro 1941a: 41, 49; 1941b: 16).

Bryan (1942: 170) reported a visit to Nihoa in September 1894 by the H.M.S. HYACINTH; soundings were taken.

Nihoa was acquired by the United States as a part of the Territory of Hawaii on 7 July 1898.

In 1902 the U.S. Fish Commission ship ALBATROSS visited Nihoa twice, 1 to 3 June and 5 to 9 August, while engaged in deep-sea explorations off the Hawaiian Islands. No landing could be made on either visit. Walter K. Fisher, one of the biologists, subsequently reported observations of 19 species of birds that were seen on or around the island (Fisher, 1903). On both visits the ALBATROSS dredged offshore to collect marine organisms (see Appendix Tables 2 and 3).

In April 1909, by Executive Order 1019, Nihoa was included in the Hawaiian Islands Bird Reservation.

Visits by the Thetis - 1904-1916

During the early 1900's Nihoa was visited often by the U.S. Revenue Cutter THETIS. Most of these visits were casual inspections which were made to discover whether birds had been molested by feather poachers, a recurring problem on several of the other northwestern Hawaiian Islands. No evidence was ever found that poachers had visited Nihoa. Lack of poaching, in all probability, was not due to insufficient numbers of birds but rather to the difficulty of landing and working on the steep slopes.

[14/] Possibly J.J. Williams who took bird photographs on Laysan Island in the 1890's.

Nihoa was sighted on 9 June 1904 but no landing was made since the ship was en route to Lisianski to apprehend Japanese who were killing birds there (Hamlet, ms.).[15]

Another visit was made by the THETIS on 12 January 1910 but this time heavy seas prevented a landing. W.V.E. Jacobs (ms.), the vessel's commander, noted that he saw no birds except the Sooty [Black-footed] Albatross and no evidence of human habitation.

The THETIS passed offshore on numerous subsequent occasions between 1910 and 1912. On one of these offshore visits (17 December 1912), George Willett (ms.), who was engaged in surveying the northwestern Hawaaian Islands for the Bureau of Biological Survey, listed eight species of birds.

The THETIS sighted Nihoa twice in 1913 but no landing was made until 7 September 1914[16] when crewmen swam ashore to collect rock specimens for Carl Elschner. One of those who swam ashore was Lt. W.N. Derby. The small sand beach on which they landed was named for him, "Derby's Landing" (Bryan, 1942: 170).

On 18 March 1915 six persons went ashore, landing on a bit of sandy beach on the south side of the island near the western end. During the day the officers made a bird survey, noting species and numbers and taking photographs.

One of the officers, Lt. W.H. Munter, later made a report in which he listed 14 species, nine of which were recorded as breeding (Munter, 1916). Two other species, the Christmas Shearwater and the Bristle-thighed Curlew, were seen by the ship's captain, J.H. Brown (ms.). Munter's obscure and little-known report was the first fairly comprehensive list of birds of Nihoa. His report also includes the earliest mention of the Nihoa Finch, later described by W.A. Bryan (1917). Although some of Munter's estimates seem high in view of more recent, detailed observations, others seem quite reasonable. On the whole the report was one of the most valuable early surveys of the birdlife of Nihoa, particularly when one considers the brevity of the visit.

While the landing party was making observations on the high slopes, the seas began to rise. The long-boat's crew lost control

---

15/ Log of the U.S. Revenue Cutter THETIS. Rec. Group 26, U.S. Nat. Archives, Washington.

16/ Elschner (1915: 9) stated that sailors swam ashore at Nihoa in May 1910, but this is evidently incorrect as an examination of the logs of the THETIS for that period reveals no such landing. Probably Elschner confused Nihoa with Necker where a landing was made on 23 May 1910.

of the boat and the coxswain severely injured his leg while trying to hold the boat in position. By the time the survey party returned the long-boat had been partially stove in and could not be used for transportation. Consequently the ship's officers had to jump into the sea from a low cliff and swim for a second long-boat.

The following year on 12 February a party from the THETIS again landed. Several officers, including Munter, again explored the island. Munter (ms.) recorded 13 species of birds, seven of which were breeding. He also collected five specimens of the then undescribed Nihoa Finch and made a collection of plant specimens.

In response to a request by the Department of Agriculture, the U.S.S. HERMES made a survey of the birdlife of the leeward chain in September 1918. Nihoa was visited on the second but, as had often happened before, heavy seas prevented a landing. White Terns, Sooty Terns, Wedge-tailed Shearwaters, albatross, and tropicbirds were noted from offshore, but no other bird observations were recorded (Diggs, ms.).

In 1919 Nihoa was visited by Gerrit P. Wilder, Warden of the Hawaiian Islands. He arrived offshore on 7 October aboard the lighthouse service tender KUKUI. The ship anchored in Adams Bay and a landing was made about 150 yards east of Derby's Landing (Anon., 1920: 560).

Visits by the Tanager Expedition

Nihoa was visited in 1923 and 1924 as a result of a cooperative scientific venture sponsored by the U.S. Navy, U.S. Biological Survey, and Bernice P. Bishop Museum. These visits, known collectively as the Tanager Expedition,[17/] are by far the most important early scientific visits.

On 24 May 1923 the TANAGER sighted Nihoa. Commander King, Alexander Wetmore, leader of the scientific party, David L. Thaanum, Theodore Dranga, Chapman Grant, and Eric L. Schlemmer took a long-boat in to look over landing possibilities but found that high surf precluded landing the whole party (Wetmore, ms.). Grant, Thaanum, and Dranga got ashore for a brief period on the rock ledge and managed to collect some molluscs and echinoids. The following day Wetmore and others tried to get ashore but sea conditions had not improved. Finally on 26 May the attempt to land was abandoned and the TANAGER sailed for Honolulu (Ball, ms.).

The following month, on another of her several cruises along the chain, the TANAGER arrived the afternoon of 10 June and the field

---

17/ The expedition received its name from the support vessel, the Navy minesweeper TANAGER, commanded by Samuel W. King.

party landed and established camp. The following day camp was set up on nearby Necker and radio communication[18/] between the two islands was established. Part of the party subsequently sailed for Honolulu, another group remained on Necker, and a third crew stayed on Nihoa (Edward L. Caum, Harold S. Palmer, Charles S. Judd, and Bruce Cartwright). On 20 and 21 June the TANAGER removed the parties from Nihoa and Necker, respectively (Gregory, 1924: 21-22). During the protracted visit hydrographic work was done, plane table topographic surveys taken, and extensive collections and studies were made of the archaeology and biota (see Appendix Table 3).

The following year the TANAGER paid another visit to Nihoa (and Necker), primarily to follow up on the archaeological work begun the previous year. The party (see Appendix Table 1) was under the leadership of Harold S. Palmer, but archaeological work was directed by Kenneth P. Emory. Although the work done during the 4-day visit (9-13 July) was primarily archaeological, data were also obtained on topography, geology, and botany (Gregory, 1925: 19-20).

Visits in the Late 1920's and Early 1930's

The U.S. Coast and Geodetic Survey Ship GUIDE, commanded by Thomas Maher, visited Nihoa in April, May, and June 1928.[19/] Most of the survey party's work was hydrographic in nature but at least one archaeological specimen was collected (Emory, 1928: 45).

On 19 August 1932 Nihoa was visited by the U.S.S. MONTGOMERY (DM 17) commanded by L.E. Clifford. The landing party saw many birds and noted a small lean-to facing south on the slope about 200 feet above Adams Bay. Remains of a radio receiver were found in the shack but no other evidence of human habitation was seen.[20/] This shack may have been built by personnel from the GUIDE during its survey of the island a few years previously.

In 1934 the U.S. Coast Guard Cutter ITASCA paid a brief visit to Nihoa to observe conditions on the island. The ship arrived late in the afternoon of 8 February but, like many preceding visitors, the crew was unable to effect a landing. After visiting Necker and French Frigate Shoals, the ship returned to Nihoa on 11 February; an even

---

18/ The exact itineraries of each individual are difficult to establish as several trips were made between the islands. Appendix Table I lists personnel known to have spent some time on Nihoa.

19/ Log of the U.S.S. GUIDE. Rec. Group 37, U.S. Nat. Archives, Washington.

20/ Report from the commanding officer, L.E. Clifford, Rec. Group 37, U.S. Nat. Archives, Washington.

heavier surf than before discouraged any attempt at landing. On both visits the ITASCA circled the island and neither time found any evidence of recent landings (Baylis, ms.).

The ITASCA circled Nihoa again on 19 June during another inspection of the northwestern Hawaiian Islands. Later that year (10 December), while searching Hawaiian waters for a missing plane, the STAR OF AUSTRALIA, the ITASCA revisited Nihoa. A private vessel, the LANIKAI, also visited Nihoa during the search for the downed Plane (Honolulu Star Bulletin, 6, 9 Feb. 1935).

On 3 March 1936, A.D. Trempe, in cooperation with the Biological Survey and five crew members of the Coast Guard vessel RELIANCE, made a three-hour inspection of the birdlife of the island. Trempe (ms.) reported seeing 14 species of birds, six of them breeding.

Visits During the 1940's and 1950's

George Vanderbilt, his wife, and Clifton Weaver paid a visit to Nihoa from a private yacht in 1940. The party arrived at Nihoa on 7 August and completed landing their gear by the afternoon of that day. The ship then departed, returning to remove the party from the island on the 16th. The party was primarily interested in ornithological observations and collections (Vanderbilt and de Schauensee, 1941).

In July 1951 Vanderbilt revisited Nihoa on the George Vanderbilt Pacific Equatorial Expedition that was collecting fish and observing seabirds. With him were: Vernon E. Brock of the Hawaii Division of Fish and Game and Robert R. Harvy of Stanford University who served as naturalists; his wife Anita and daughter Lucille; Jack Lance, a sport-fishing guide; and T. Ivar Vatland and Baba Green, the captain and crew, respectively, of the PIONEER. Little has been reported about this visit and we know of no zoological publications resulting from it (see Herald, 1952; Harry, 1953).

Nihoa was visited twice in the early 1950's by Frank Richardson of the University of Washington. Richardson made observations on the occurrence and breeding activities of seabirds. Both visits, one 21 to 22 December 1953, the other on 18 March 1954, were made from the Coast Guard vessel BUTTONWOOD. Thirteen species of birds were recorded on the first visit and 11 on the second (Richardson, pers. comm.).

The AUKAKA, owned by a Honolulu insurance man, David G. Nottage, paid a visit to Nihoa in 1955. Aboard were Nottage and his brother Peter; George Carter, a Pearl Harbor mechanic; Ed Sheehan, a Honolulu radio announcer; and Ivan T. Rainwater, an airport supervisor with the plant quarantine branch of the U.S. Department of Agriculture. Rainwater, an amateur archaeologist, had been detailed to collect specimens of charcoal for radioactive carbon dating by Dr. K.P. Emory

of the Bishop Museum. Other objectives were the collection of plants, and the capture of frigatebirds for the Honolulu Zoo. The party arrived early on 21 August and visited the island daily until 24 August when a final departure was made at 1100 (Honolulu Advertiser, 28 Aug., 1955; Sheehan, 1966).

Dale W. Rice and Karl W. Kenyon made a low-level photographic aerial survey of Nihoa on 28 December 1957. Their purpose was an accurate census of the albatross and seal populations.

Visits During the 1960's

Nihoa was visited 5 to 15 March 1961 by the U.S.S. DUVAL COUNTY which was conducting the first phase of a military project to establish first order astronomic stations, HIRAN, and azimuth marks on the northwestern Hawaiian Islands in connection with the Hawaiian geodetic survey. Transportation between the ship and the island was by helicopter (Roach, ms.).

One of the more extensive surveys of Nihoa was made the following December by Raymond J. Kramer and Gerald Swedberg, biologists with the Hawaii Division of Fish and Game. They landed on the island by helicopter from the U.S.S. FLOYD COUNTY which was engaged in Phase II of the HIRAN project. They landed about noon on 9 December and left the island early in the morning of the 15th (Kramer, ms.).

During their stay detailed notes were made on the status of the two endemic landbirds, the Nihoa Finch and the Nihoa Millerbird, and on the status and distribution of the various species of vascular plants occurring on the island.

Several of their botanical observations are of particular interest since they indicate distinct changes in the vegetation since the detailed survey made by the Tanager Expedition in 1923. Kramer and Swedberg's careful count of the endemic palms (*Pritchardia remota*) revealed a total of 283 palms as compared with 515 in 1923.

Brief notes were taken on seabirds and shorebirds. Eleven species of seabirds and two of shorebirds were recorded.

At the time of the biologists' visit, they found four military personnel, two from the Air Force and two from the Army, who had been living on the island for 2 weeks and who left Nihoa with the biologists.

Kramer, accompanied by David H. Woodside, John W. Beardsley, and David B. Marshall, revisited Nihoa for about 7 hours on 10 June 1962 during the HIRAN II project. During their visit the biologists made brief notes on vegetation and birdlife, collected arthropods, and examined the island to determine what effect the HIRAN operations had had on its ecology. They found two species of plants (*Cenchrus* sp., *Paspalum* sp.), evidently introduced by the military, growing at the HIRAN antennae sites.

The Bureau of Sport Fisheries and Wildlife (BSFW), now no longer a separate entity but subsumed within the U.S. Fish and Wildlife Service, assumed responsibility for the management, inspection, and patrol of the Hawaiian Islands National Wildlife Refuge in 1964 when a refuge manager was assigned to Honolulu. Since then at least one landing, and usually two, were made each year.[21/] On six of these recent visits (Table 1) BSFW survey parties were composed in part of personnel from the Smithsonian Pacific Ocean Biological Survey Program (POBSP) which investigated the biota of the central Pacific from 1963 until mid-1969.

During these often brief visits Refuge personnel were primarily concerned with administrative and management duties, and with studies of the populations and breeding status of albatrosses, the Nihoa Millerbird, and the Nihoa Finch. POBSP activities were primarily directed towards obtaining data on occurrence, numbers, and breeding status of seabird populations. Data gathered during these visits, and much hitherto unpublished data from earlier visits, form the basis for the faunistic accounts presented in following sections of this report.

In 1967 Nihoa and other islands of the Refuge were designated a "natural area" by the Bureau of Sport Fisheries and Wildlife. This means that the Refuge management is seeking, as far as is possible, to prevent any disturbance of the ecology of the islands. Landings may be made only by permit from the Bureau, and visits are restricted to personnel involved in scientific studies.

VEGETATION
by Derral Herbst[22/]

Low shrubs, seldom above 1 meter high, cover the sides and much of the floors of the valleys (Figs. 16-17). These consist primarily of *Solanum nelsoni*, *Chenopodium oahuense* and *Sida fallax*, and may be mixed or in almost pure stands. Less common elements include *Sesbania tomentosa*, *Euphorbia celastroides* and *Eragrostis variabilis*. Of the very few plants of the annual grass *Panicum torridum* sighted in August 1968, all but one were young seedlings. The shrubs are sparser and the tufts of *Eragrostis* more common on the ridges. Intertwining branches of the scrambling *Euphorbia* shrubs form dense mats around rock outcroppings along the edges of the north cliffs (Fig. 18). In August 1968 Herbst did not notice well defined vegetative associations, although these are found on other northwestern Hawaiian Islands.

21/ Appendix Tables 1 to 3 summarize personnel, accomplishment, and papers resulting from these and earlier visits.

22/ Department of Botany, University of Hawaii, Honolulu, Oahu, Hawaii 96822.

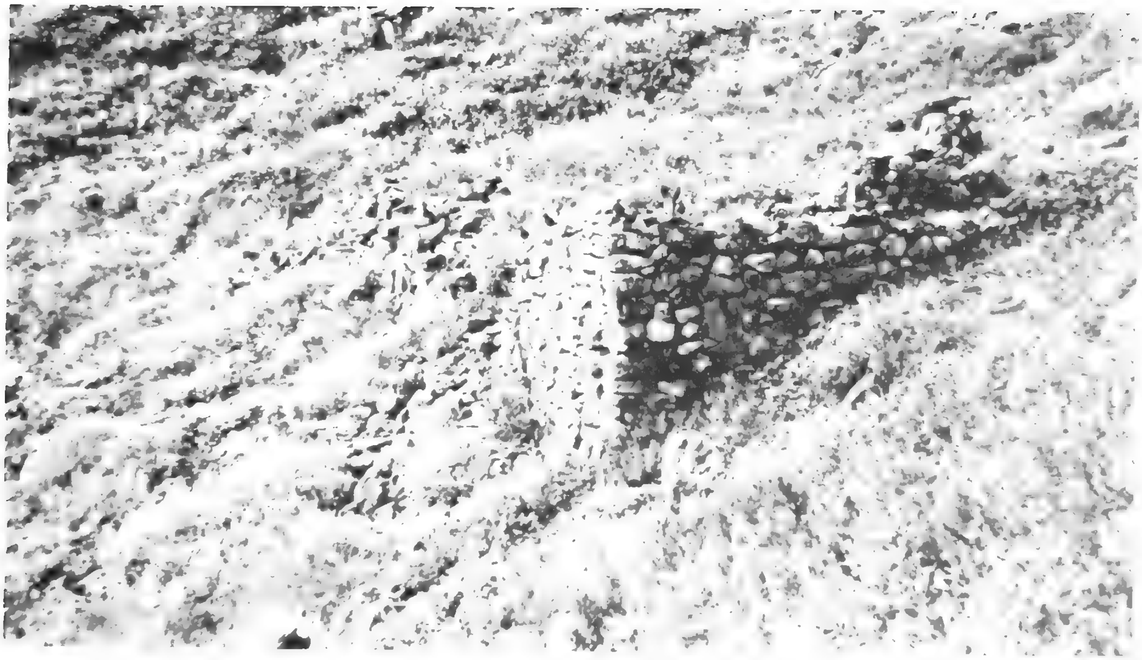


Figure 16. Remains of ancient house terrace in East Palm Valley, August 1968. Vegetation is chiefly *Chenopodium* shrubs with some *Sida*. Photograph by Derral Herbst.

Figure 17. Middle Valley, August 1968; vegetative cover--typical of the sides of the valleys--consists primarily of 2 to 3 foot tall *Sida* and *Chenopodium* shrubs. Photograph by Derral Herbst.

231-338 O - 77 - 10

The first recorded botanical collection was made by a Dr. Rooke in 1858 when he brought specimens of the Nihoa loulu, *Pritchardia remota*, to Honolulu (Hillebrand, 1888: 451). Later collections were made by the following: Capt. J.H. Brown of the U.S. Revenue Cutter THETIS, September 1914; E.L. Caum, E.H. Bryan, Jr., C.M. Cooke, Jr., and C.S. Judd, June 1923; E. Christophersen and T.T. Dranga, July 1924; R.J. Kramer and G. Swedberg, December 1961; J.W. Beardsley, June 1962; C.R. Long, September 1964; E. Kridler, J.L. Sincock, and D. Herbst, August 1968; and D. Yen, May-June 1969.[23/]

The following annotated list includes all species of vascular plants known from Nihoa Island. Twenty species were collected during the Tanager Expedition visits of 1923-1924--three species and three varieties subsequently being described as new (Christophersen and Caum, 1931). Additional species collected subsequently and not previously reported were *Portulaca oleracea*, collected by Long in 1964, *Cenchrus echinatus* var. *hillebrandianus*, collected by Herbst in 1968, and *Setaria verticillata* and *Ipomoea pes-caprae*, collected by Yen in 1969. These, together with a sighting of a grass (*Paspalum* sp.), that has not been collected, bring the total number of species of vascular plants known to have grown on Nihoa to 25.

Magnusson (1942) published a list of lichens and Tsuda (1966) included two algae from Nihoa in his enumeration of the marine benthic algae from the Northwestern Hawaiian Islands. The specimens cited below are deposited in the B.P. Bishop Museum Herbarium (BPBM) or in the Herbarium of the University of Hawaii (UH).

Annotated Species List

Gramineae

Cenchrus echinatus var. *hillebrandianus* (Hitchc.) F.B.H. Brown
C. hillebrandianus Hitchcock

Herbst 1206 (UH), Yen 1010 (BPBM). Kramer (ms.) reported finding and burning, in 1961, six *Cenchrus* spikelets which were stuck to a towel of one of the HIRAN personnel. Herbst found two plants growing in a pocket of soil on the floor of Miller Valley in 1968. Both were removed and the area searched for seeds. Apparently these efforts were in vain, as this plant is included in the 1969 collections of Douglas Yen.

[23/] Plants were also collected in February 1916, August 1955, and in March 1964 (see Appendix Table 2) but we do not know the present disposition of these collections.

Eragrostis variabilis (Gaud.) Steud.

Caum 61 (BPBM), Long 2417 (UH), Herbst 1208 (UH), Yen 1009 (BPBM). Found widespread over the island as in 1923-1924 but observers in both December 1961 and September 1964 believed this species was less abundant than indicated by Christophersen and Caum.

Panicum torridum Gaud.

Caum 60 (BPBM), Christophersen 5 (BPBM), Kramer and Swedberg 7 (BPBM), Long 2408 2432 (UH), Herbst 1209 (UH), Yen 1011 (BPBM). Widely distributed in 1923. Observers in December 1961 and September 1964 believed this species to be more abundant than indicated by Christophersen and Caum. Only a few plants were seen in August 1968, however.

Paspalum sp.

Found growing in the vicinity of the HIRAN area of operations in June 1962 (Kramer and Beardsley, ms.). Not seen subsequently.

Setaria verticillata (L.) Beauv.

Yen 1012 (BPBM). Near south coast, May, 1969.

Palmae

Pritchardia remota Becc.

Dr. Rooke in 1858 (mentioned in Hillebrand, 1888: 451; not seen), Brown s.n. (BPBM), two sheets, one with Rock's no. 10347, Caum 72 (BPBM), Cooke 299 (BPBM), Christophersen 9a (BPBM), Long 2412, 2440, 2443 (UH). This endemic species of palm, found only in East and West Palm Valleys (Figs. 19-20), is the most conspicuous component of the flora. A few trees--most of which are mature--grow at the bases of basaltic cliffs on the steep outer slopes of each valley. Most of the population, however, is crowded into small, dense groves on the terraces lower in the valleys. Kramer (ms.) suggests that their distribution may be determined by soil depth and availability of water. The faces of the cliffs may act as natural catchment areas which would add to the moisture at their bases, while part of the run-off during rains would be held by the deep accumulations of debris in the ancient, man-made terraces.

The palms have been counted four times in the last 45 years. In June 1923 C.S. Judd counted 347 trees in West Palm Valley and 168 in East Palm Valley. The count did not include small seedlings (Christophersen and Caum, 1931: 6). In December 1961 Kramer and Swedberg counted 229 trees in West Palm Valley and 54 in the east valley. Seedlings under one meter were omitted, and immature fruits were noted on some of the plants (Kramer, ms.). C.R. Long divided

Figure 18. Low scrambling *Euphorbia* shrubs around rock outcroppings along northern cliffs, August 1968. In the foreground are *Chenopodium* and *Solanum* shrubs. Photograph by Derral Herbst.

Figure 19. Small grove of *Pritchardia remota* at base of cliff in upper East Palm Valley, August 1968. Photograph by Derral Herbst.

his count of September 1964 into six localities: West Palm Valley contained 107 seedlings, 148 non-flowering or non-fruiting trees, and 127 with flowers or fruit; East Palm Valley had 32 seedlings, 69 non-flowering or non-fruiting, and 46 with flowers or fruits. Long's total is 390 mature trees and 139 seedlings. Herbst attempted to follow Long's system when he counted the trees in August 1968. His census follows: in the west valley, 142 seedlings, 106 non-flowering or non-fruiting and 139 with flowers or fruits; in the east valley, 238 seedlings, 11 non-flowering or non-fruiting plants and 43 with flowers or fruits. The total of 516 palms does not include the very young seedlings with less than five leaves.

Kramer attributed the decline in the palm population to the excessive crowding of the trees in the terraces and to a natural thinning of a long-range cycle of the population. Herbst's observations of this species and of the growth rate of closely allied species on Oahu left little doubt in his mind that the discrepancies between the counts lay primarily in the lack of a uniform definition of the word "seedling." In addition, the difficulty of counting the palms is aggravated by the density of the population and by the numerous, vociferous seabirds that nest in the trees. The population probably has remained fairly static over the last 45 years.

In August 1968 mature fruits were collected from both valleys and were distributed to the Lyon Arboretum of the University of Hawaii, Honolulu, and the Foster Botanic Garden, also located in Honolulu.

Polygonaceae

Rumex giganteus Ait.

Caum 71 (BPBM), Christophersen 8 (BPBM), Long 2411 (UH), Yen 1015 (BPBM). Has been found only in the Devil's Slide-Miller Peak area. Sterile in September 1964 and August 1968.

Chenopodiaceae

Chenopodium oahuense (Mey.) Aellen
C. sandwicheum Moq. f. *microspermum* Aellen

Caum 58, 67 (BPBM), Judd 1 (BPBM), Christophersen 7 (BPBM), Kramer and Swedberg 6 (BPBM), Long 2410, 2413, 2418, 2444 (UH), Yen 1019 (BPBM). Widespread; one of the most common, if not the most common, plant on the island (Fig. 6).

Amaranthaceae

Amaranthus brownii Christophersen and Caum

Caum 73 (BPBM), Judd 2 (BPBM), Yen 1013 (BPBM). Caum and Judd made the first collections of this plant in June 1923, observing that

it was "most common on the ridge leading to Miller Peak, but [was] abundant also on the ridges to the east" (Christophersen and Caum, 1931: 6). This endemic species was not seen again until May 1969, when Yen found four plants growing near the summit of Miller's Peak. The region around Miller's Peak was traversed by most, if not all, of the parties recently visiting Nihoa. It does not seem likely that other botanists would have missed the plant. However, *Amaranthus brownii* is an annual and the ridges are the driest part of the island. If it has the delayed germination period and the rapid life cycle that are common in many annuals, it could easily have been missed by the botanists who collected during August, September and December.

Nyctaginaceae

Boerhavia repens L.
B. diffusa L.

Bryan 3a (BPBM), Caum 79 (BPBM). In 1923 it was found only on the sandy beach in Adams Bay and may have washed away. Not collected or seen since 1923.

Aizoaceae

Tetragonia tetragonioides (Pallas) O. Kuntze
Tetragonia expansa Murray

Caum 80 (BPBM), Christophersen 2 (BPBM). Christophersen and Caum (op. cit.) listed it as "rare, found only just above the sand beach and on steep rock faces west of it." Possibly the corky buoyant fruits floated to Nihoa from one of the main islands and although at least one generation grew there, the species apparently failed to become established. Not collected since 1924.

Portulacaceae

Portulaca lutea Sol

Caum 65 (BPBM), Kramer and Swedberg 1 (BPBM), Yen 1002 (BPBM).

Portulaca oleracea L.

Long 2431 (UH), Herbst 1204, 1205 (UH), Yen 1001 (BPBM).

Portulaca villosa Cham.
P. caumii F.Br.

Caum 66 (BPBM), Kramer and Swedberg 3 (BPBM), Long 2414, 2433 (UH), Herbst 1207 (UH), Yen 1003 (BPBM). *Portulaca caumii* was described as a new species by F. Brown in 1931 (in Christophersen and Caum, 1931: 29) with Caum 66 designated as the type. Brown states that *P. caumii* is "allied to *P. villosa* Chamisso, from which it differs in the color of the flower, the commonly flat leaves and the smaller,

minutely rugous seeds." Egler (1938: 265)--after studying living plants of *P. villosa* from Koko Head on Oahu and the islet of Kauhikaipu near Oahu, and from the collections of the Bishop Museum --states that "with the possible exception of a statement of petal color," all characters listed from the Nihoa species existed in the portulacas of Oahu. The Nihoa specimen collected by Caum had white petals, while those of *P. villosa* generally have the outer third to outer half pink. However, Egler did find plants with entirely white petals in the colony on Kaohikaupu. Stone (1963) concurs with Egler's conclusions.

After observing plants from Nihoa and Kaohikaipu, grown in the botany greenhouse of the University of Hawaii, Herbst concurs with Egler's conclusions and notes that a number of plants on Nihoa had deep pink or pink-tipped petals in August 1968. These plants were found at an elevation of 165 meters in West Palm and Miller Valleys.

On Nihoa, *P. lutea* grows in shallow, rocky soil and in cracks along the lower south side; a large colony was found in August 1968 near the remains of a heiau (temple) at the northeast end of Miller Plateau. *Portulaca villosa* was found in pockets of soil and in cracks throughout the island (Fig. 21). An introduced species, *P. oleracea*, occurs in two places, the largest colony being on Miller Plateau. A smaller colony, probably established within a year of the August 1968 visit, is located at the base of Miller Valley on a small rise usually used as a campsite by recent survey parties.

Seeds of *P. oleracea* probably were introduced accidentally during the HIRAN operation in 1961 when the Miller Plateau area was used as a helicopter landing pad and campsite.

Caryophyllaceae

Schiedea verticillata F. Br.

Bryan 2 (BPBM), Caum 70 (BPBM), Christophersen 3 (BPBM), Kridler and Sincock, s.n. (UH), Herbst 1210a (UH), Herbst 1401 (BPBM, UH), Yen 1005 (BPBM). In 1923-1924 "seen only on the cliff west of the sand beach, and north of Millers Peak, just below the summit" (Christophersen and Caum, 1931: 6). Two fleshy roots just beginning to send out new leaves were collected by Kridler and Sincock in August 1968, about half-way down Devil's Slide; specimens from one of the roots, grown in the botany greenhouse, Manoa Campus, University of Hawaii, were listed under Herbst's no. 1401. Seeds from Herbst no. 1401 were later distributed to the Foster Botanic Garden and the Lyon Arboretum. Herbst 1210a, consisting of a dried fragment of a plant, was found at about 165 meters elevation in West Palm Valley. Yen 1005 was collected on the south face of the cliffs of Dog's Head (west end), adjacent to Emory's site No. 2 (Emory, 1928: 18).

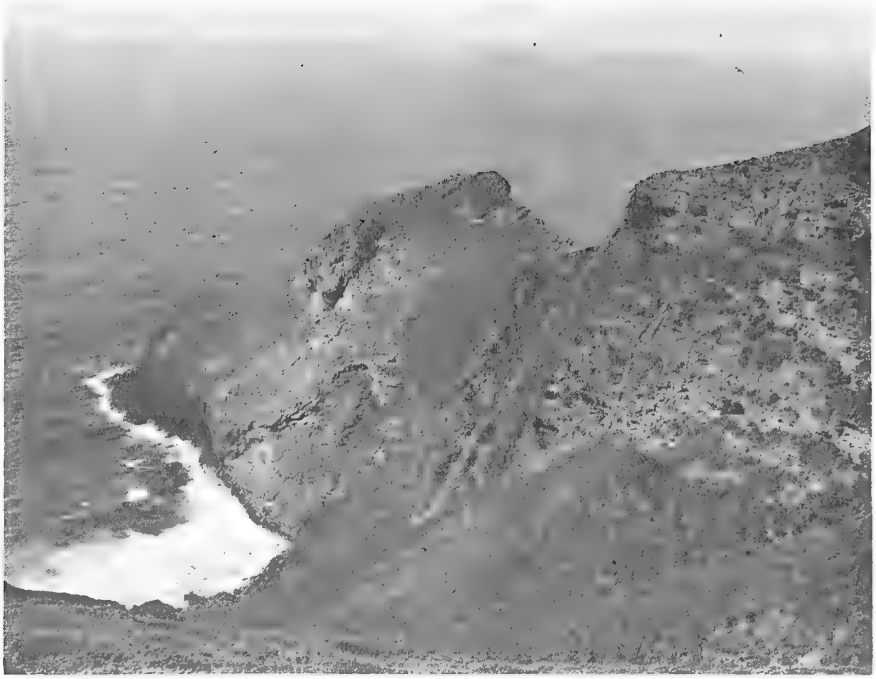


Figure 20. Grove of *Pritchardia* (right foreground) in West Palm Valley, 10 June 1962. BSFW photograph by David B. Marshall.

Figure 21. *Portulaca villosa* plant growing from crack in face of stone ledge, August 1968. Photograph by Derral Herbst.

Leguminosae

Sesbania tomentosa H. and A.

Bryan 5 (BPBM), Caum 63 (BPBM), Judd 3 (BPBM), Christophersen 4 (BPBM), Kramer and Swedberg 2 (BPBM), Long 2409, 2428 (UH), Yen 1016 (BPBM). As in 1923-1924, *Sesbania* is now distributed widely over the island. Found flowering in December 1961 and June 1962.

Zygophyllaceae

Tribulus cistoides L.

Bryan 2a (BPBM), Caum 78 (BPBM), Long 2420 (UH). In 1923 "observed only at the foot of the ridge leading up to Miller's Peak, just above the cliff" (Christophersen and Caum, 1931: 6). In 1962 found in flower at the bottom of West Palm Valley (Kramer and Beardsley, ms.). Last collected in September 1964 when it was found on the south side of the cliffs on the upper slopes.

Euphorbiaceae

Euphorbia celastroides Boiss.

Bryan 6 (BPBM), Caum 64 (BPBM), Judd 5 (BPBM), Kramer and Swedberg 10 (BPBM), Long 2405, 2430 (UH), Yen 1014 (BPBM). Common on the edge of the cliffs in 1923-1924 and on recent visits (Fig. 22)

Malvaceae

Sida fallax Walp.

Caum 69 (BPBM), Bryan 1a (BPBM), Judd 4 (BPBM), Kramer and Swedberg 8, 11 (BPBM), Long 2421, 2429, 2437 (UH), Yen 1004 (BPBM). Common over entire island.

Convolvulaceae

Ipomoea indica (Burm.) Merr.
I. insularis (Choisy) Steud.
I. congesta R. Br.

Caum 83 (BPBM), Christophersen 1 (BPBM), Kramer and Swedberg 9 (BPBM), Long 2427 (UH), Yen 1017 (BPBM). In 1923-1924 "observed in the gorge just below Millers Peak, at the base of the pinnacle on the west cliff, and above the sand beach" (Christophersen and Caum, 1931: 6). Seen in the former area in 1961.

Ipomoea pes-caprae (L.) Sw.

Yen 1007 (BPBM). Collected from stony south face adjacent to the east slope of the mouth of West Palm Valley; elevation about 35

meters. A littoral species cosmopolitan in the tropics and subtropics. Its large, buoyant seeds were doubtless carried to the island by ocean currents and deposited at the mouth of West Palm Valley--an area to which several strand species have been restricted.

Boraginaceae

Heliotropium curassavicum L.

Bryan 4 (BPBM), Caum 77 (BPBM), Christophersen 6 (BPBM), Long 2436 (UH), Yen 1008 (BPBM). Collected from the sand beach at the base of West Palm Valley and the immediately adjacent area in 1923, 1924, and 1964. In September 1964, 27 plants were counted mainly on the slopes above the beach.

Solanaceae

Solanum nelsoni Dunal
S. nelsoni var. *caumii* F.Br.
S. nelsoni var. *acuminatum* F.Br.

Bryan 3 (BPBM), Caum 68, 84 (BPBM), Judd 6, 7, 8 (BPBM), Kramer and Swedberg 5, 12 (BPBM), Long 2424, 2434, 2339 (UH), Herbst 1210 (UH), Yen 1018 (BPBM). Found commonly over the island (Fig. 23).

Solanum nigrum L. var. *nihoense* F. Br.

Caum 62 (BPBM). Two plants were seen in 1923 "one on the edge of the southern cliff, about the middle of the island, and the other in the pocket of a stream bed just above the sand beach" (Christophersen and Caum, 1931: 6-7). Not reported subsequently.

Cucurbitaceae

Sicyos nihoaensis St. John

Christophersen and Dranga 9 (BPBM), Kramer and Swedberg 4 (BPBM), Beardsley s.n. (BPBM), Yen 1006 (BPBM). This species, previously identified as *Sicyos pachycarpus* H. and A., has recently been described as a new species by St. John (1970). It was found only below Tanager Peak in 1924. Several patches found just below and south of the highest Pritchardias in West Palm Valley in 1961. In 1962 found in the HIRAN camp area on Miller Plateau.

Plant Affinities

Of the 25 taxa known from Nihoa, four species and one variety are endemic to the island:

Pritchardia remota	*Schiedea verticillata*
Amaranthus brownii	*Solanum nigrum* var. *nihoense*
	Sicyos nihoanensis

Figure 22. *Euphorbia celastroides*, August 1968. A variety with the same habit growing in a somewhat similar environment at Kaena Point, Oahu, was in flower at this time but was leafless. Photograph by Derral Herbst.

Figure 23. The *Solanum nelsoni* flowers on Nihoa in August 1968 had a white corolla and purple anthers; those of Moomi Beach, Molokai, have light blue petels.

Among the remaining taxa, eight are restricted to the Hawaiian Islands:

Eragrostis variabilis
Panicum torridum
Rumex giganteus
Chenopodium oahuense
Sesbania tomentosa
Euphorbia celastroides
Solanum nelsoni
Portulaca villosa

Seven taxa are native to Hawaii, but are distributed widely throughout the Pacific:

Boerhavia repens
Portulaca lutea
Tribulus cistoides
Sida fallax
Ipomoea indica
Ipomoea pes-caprae
Heliotropium curassavicum

The remaining taxa are not native to Nihoa, to Hawaii or the Pacific:

Cenchrus echinatus var. *hillebrandianus*[24/]
Paspalum sp.
Tetragonia tetragonioides
Portulaca oleracea
Setaria verticillata

To summarize: of the 25 taxa of vascular plants known from Nihoa, 20 are native to the Hawaiian archipelago; of the 13 taxa endemic to the Hawaiian archipelago, 5 are restricted to Nihoa.

TERRESTRIAL VERTEBRATES

Species Accounts

Common names of seabirds follow King (1967) in the following species accounts. Taxonomic order follows that of Peter's (1931, 1934) Checklist of Birds of the World, volumes I and II, with the exception of the Procellariiformes which follow Alexander *et al.* (1965), the Charadriidae and Scolopacidae which follow Jehl (1968), and the Sulidae which follow the A.O.U. Checklist (1957). The scientific name of the Wandering Tattler has been modified to follow the latest supplement to the A.O.U. Checklist (A.O.U., 1973).

The species accounts which follow are set forth in a standard format which is used throughout except in those instances (e.g., accounts of vagrants) where its use would be inappropriate. The section headed Status gives the maximum recent population estimate, delimits periods of occurrence and breeding, and briefly indicates areas of the island used for nesting. The maximum recent estimate is the maximum estimate obtained since 1960. These estimates, as well as those others listed in the tables of observations are meant to

---

[24/] Variety native to Hawaii.

represent the maximum number of flying birds present during any one survey. Such estimates include breeding and non-breeding adults, subadults, and flying immatures but do not include dependent non-flying young.

The section entitled Populations discusses numerical estimates in part attempting to discover whether there have been any historical changes in population levels and in part to analyze seasonal population changes. Most population numbers were based on visual estimates supplemented by nest counts and banding data. For the two endemic subspecies of birds, the Nihoa Millerbird and Nihoa Finch, recent estimates were usually based on randomly chosen transect censuses. In these transects, usually 16.5 feet wide and 200 to 250 feet long, all birds of either species seen were counted. Usually about 50 transects were covered and a total area of about 4 to 5 acres was sampled. Standard deviation was calculated from the results of the transect counts to obtain 95 percent confidence levels.

The section entitled Annual Cycle contains an attempt, based on all available data, to determine the reproductive cycles and, where possible, to pinpoint peaks of breeding activity. The section headed Breeding Habitat specifies areas or habitats which seem particularly favored by the species under discussion.

The section headed Banding summarizes all known bandings by the POBSP and BSFW and the section headed Specimens lists the locations of all specimens from Nihoa of which we are aware. The specimens cited are deposited in the American Museum of Natural History (AMNH), Bernice P. Bishop Museum (BPBM), Los Angeles County Museum (LACM), Museum of Comparative Zoology (MCZ), Philadelphia Academy of Natural Sciences (PAS), State University of Iowa (SUI), and United States National Museum of Natural History (USNM). These two latter sections are omitted if we have no records indicating that the species has ever been banded or collected on Nihoa.

Birds

In all, 27 species of birds have been recorded from Nihoa Island (Table 2). Eighteen of these are seabirds, all but one of which (the vagrant Red-billed Tropicbird) breed on Nihoa. The remaining avifauna consists of four migrant shorebirds, three vagrants (the Herring Gull, Pintail, and Mockingbird) and two endemic passerines, the Nihoa Finch and the Nihoa Millerbird.

Most species exhibit a distinct annual breeding cycle but in some species at least a few individuals can be found breeding in every month of the year. It seems likely that the birds of Nihoa, like those on other northwestern Hawaiian Islands more intensively studied, vary initiation of nesting by up to several weeks from year to year. This certainly appears to be the case for the Gray-backed Terns and Sooty Terns on Nihoa and may well apply to other species as well.

Comparison (Table 3) of peak egg laying periods on Nihoa with those on Laysan, a more westerly island in the leeward chain, and with those on Kure Atoll, westernmost of the northwestern Hawaiian Islands, reveals that some species show distinct geographical variation in their reproductive cycles. In general, peak laying periods on Laysan and Kure are in rough accord but it appears that on Nihoa at least five species breed earlier than on the outlying islands. At present we have no adequate explanation for these differences in breeding regimes.

Table 2. The avifauna of Nihoa Island.

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
ORDER PROCELLARIIFORMES		
FAMILY DIOMEDEIDAE		
Diomedea nigripes Black-footed Albatross	Uncommon breeder	120-130; March 1964
Diomedea immutabilis Laysan Albatross	Rare breeder	40; July 1973
FAMILY PROCELLARIIDAE		
Bulweria bulwerii Bulwer's Petrel	Abundant breeder	250,000; July-August 1966
Puffinus pacificus Wedge-tailed Shearwater	Abundant breeder	20,000-31,000; July-August 1966
Puffinus nativitatis Christmas Shearwater	Common breeder	800; March 1965
FAMILY HYDROBATIDAE		
Oceanodroma tristrami Sooty Storm Petrel	Uncertain; almost certainly breeds in at least small numbers	150; March 1965
ORDER PELECANIFORMES		
FAMILY PHAETHONTIDAE		
Phaethon aethereus mesonauta Red-tailed Tropicbird	Vagrant	*
Phaethon rubricauda Red-tailed Tropicbird	Common breeder	375-625; July-August 1966

Table 2. (Continued)

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
FAMILY SULIDAE		
Sula dactylatra Blue-faced Booby	Common breeder	350; March 1968
Sula leucogaster Brown Booby	Common breeder	225; March 1968
Sula sula Red-footed Booby	Common breeder	3,500; March 1965
FAMILY FREGATIDAE		
Fregata minor Great Frigatebird	Abundant breeder	10,000; March 1964
ORDER ANSERIFORMES FAMILY ANATIDAE		
Anas acuta Pintail	Vagrant	2; September 1971
ORDER CHARADRIIFORMES FAMILY CHARADRIIDAE		
Pluvialis dominica Golden Plover	Uncommon migrant	50; March 1965
FAMILY SCOLOPACIDAE		
Numenius tahitiensis Bristle-thighed Curlew	Uncommon migrant	5; September 1972
Heteroscelus incanus Wandering Tattler	Uncommon migrant	2; September 1972
Arenaria interpres Ruddy Turnstone	Common migrant	200; March 1968
FAMILY LARIDAE		
Larus argentatus Herring Gull	Vagrant	1; March 1965
Sterna lunata Gray-backed Tern	Abundant breeder	10,000; March 1967

Table 2. (Continued)

Taxa	Current Status	Maximum Estimate since 1960 and when recorded
Sterna fuscata Sooty Tern	Abundant breeder	100,000; March 1965
Procelsterna cerulea Blue-gray Noddy	Common breeder	2,500; July-August 1966
Anous stolidus Brown Noddy	Abundant breeder	20,000; July-August 1966
Anous tenuirostris Black Noddy	Common breeder	several or low thousands; March 1967, September 1971
Gygis alba White Tern	Common breeder	3,000; August 1971
ORDER PASSERIFORMES		
FAMILY SYLVIIDAE		
Acrocephalus familiaris kingi Nihoa Millerbird	Common endemic breeder	625; September 1967
FAMILY DREPANIDIDAE		
Psittatrostra cantans ultima Nihoa Finch	Abundant endemic breeder	6,686; August 1968
FAMILY MIMIDAE		
Mimus polyglottos Mockingbird	Vagrant	1; August 1971

* Recorded once in 1923.

231-338 O - 77 - 11

Table 3. Periods of peak egg-laying on three northwestern Hawaiian Islands

Species	Nihoa Island	Laysan Island*	Kure Atoll**
Wedge-tailed Shearwater	Probably June	June	Late June to early July
Christmas Shearwater	May or June	Late April to mid-May	Early or mid-May
Red-tailed Tropicbird	Mid- or late April	Late April to early June	May to mid-June
Blue-faced Booby	March and April	Late March to mid-April	Variable--February to April
Brown Booby	February	May (?)	May to June
Red-footed Booby	February and March	April or May	Variable--mid-March to early June
Great Frigatebird	Late February to March	March	April
Gray-backed Tern	Variable--from February to June	Mid- to late April	Mid-April to mid-May
Sooty Tern	Late February and early March	Mid-May to mid-June	May
Brown Noddy	Variable--usually June or July	Mid-May to early June	May to June
White Tern	Insufficient data	Late April to late May	Late April to early May

* Data from Ely and Clapp, 1973.

** Data from Woodward, 1972.

BLACK-FOOTED ALBATROSS *Diomedea nigripes*

Status

Uncommon breeder; maximum recent breeding population estimate: 120 to 130. Present and breeding from at least December[25/] through June; probably absent from July through at least the middle of October. Nests on the ground in the Miller Plateau area.

Populations

Estimates from the 1915 survey (Table 4) are so large in comparison to all others that we believe they are probably erroneous. Wetmore's 1923 estimate, and all but one of the more recent estimates that have incorporated careful observations of the Miller Plateau area, have consistently indicated a breeding population of about 100 to 130 birds.

Reports from a number of March visits indicate that the number of young present may vary considerably. This may indicate either that the number of breeding birds varies from year to year or that mortality may be considerably greater in some years. No evidence of mortality was found in July 1964, July-August 1966 and August 1968 so it seems more likely that the former hypothesis is correct.

Annual Cycle

The scant data indicate that birds lay at least by early December and that all young hatch by early March. Young apparently fledge by mid-July since none has been seen at the end of that month or later.

Breeding Habitat

All observers who noted the location of Black-footed Albatross nests stated or indicated that this species was confined to areas of little vegetation on Miller Plateau, north and northwest of Miller's Peak.

Munter (1915: 132) described an area which was likely Miller Plateau. He noted that the colony was located on "a plateau several acres in extent...near the highest part of the island." Similarly, Wetmore (ms.) noted that the colony was "on a small flat below the pinnacle point of Miller's Peak at a point about 850 feet above the sea." The Miller Plateau area was the only one where these birds were found nesting in December 1961 and March 1964, 1965, and 1968.

25/ These albatross almost certainly return earlier than December, judging from observations on other northwestern Hawaiian Islands, but direct observational evidence is unavailable for the late fall and early winter on Nihoa.

Banding

The BSFW banded 186 Black-footed Albatross on recent visits to Nihoa: 50 young in March 1964, 35 young and 41 adults in March 1965, and 60 young in March 1968. None has been recaptured.

Specimens

Only one Black-footed Albatross, a male (USNM 300832), has been collected on Nihoa. It was collected by Wetmore on 12 June 1923.

Table 4. Observations of Black-footed Albatross on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	A number seen some miles west of island (Fisher, 1903: 778).
	5-9 Aug.	?	None seen from offshore (Fisher, 1903: 779).
1915	18 Mar.	500 (2,000)	Young were still in "pin feathers" [probably means birds were still downy] (Munter, 1915: 132). Alternate estimate by Brown (ms.).
1916	12 Feb.	?	Nesting on Miller Plateau. About as abundant as Laysan Albatross (Munter, ms.).
1923	5 Apr.	?	Seen offshore (Wetmore, ms.).
	11-16 June	120*	Only 3 adults seen but 60 well grown young found, some with wings fully feathered (Wetmore, ms.).
1936	3 Mar.	?	Evidently nesting (Trempe, ms.).
1940	7-15 Aug.	0	(Vanderbilt and de Schauensee, 1941: 8).
1953	21-22 Dec.	0(?)	Only part of island surveyed (Richardson, pers. comm.).
1954	18 Mar.	0(?)	Only part of island surveyed (Richardson, pers. comm.).
1957	28 Dec.	100*,+	An estimated 50 nests present (Rice and Kenyon, 1962: 377).

Table 4. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	50	Many incubating eggs (Kramer, ms.).
1962	10 June	?	Only 5 young seen, downy on head but capable of flight (Kramer and Beardsley, ms.).
1963	5-6 June	?	One seen offshore (POBSP).
1964	6-7 Mar.	120-130*	50 young banded, about 10-15 more present (BSFW, POBSP).
	25 July	0	(BSFW).
	23-24 Sept.	0	(BSFW, POBSP).
1965	13-14 Mar.	80-90*	35 young banded. Possibly 5 or 10 more present (BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	?	5 birds seen about ship; breeding area on Miller Plateau not censused (BSFW, POBSP).
	13-14 Sept.	0	(BSFW).
1968	7-9 Mar.	120-124*	60 young banded on Miller Plateau. 1 or 2 more may have been present (BSFW, POBSP).
	24-27 Aug.	0	(BSFW).
1969	21 Mar.	?	None observed, but primary nesting area on Miller Peak not visited (BSFW).
1970	15 Aug.	0	(BSFW).
1971	18-19 Aug.	0	(BSFW).
	15 Sept.	0	(BSFW).

Table 4. (Continued)

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1972 16 Sept.	0	(BSFW).
1973 31 July	0	(BSFW).

* Number of breeding birds utilizing island.

+ Aerial observations only.

LAYSAN ALBATROSS *Diomedea immutabilis*

Status

Rare breeder; maximum recent breeding population estimate: 40. Present from at least December (see footnote 25 in the Black-footed Albatross species account) through May or June, but may not breed in all years. Nests on the ground, primarily in the Miller Plateau area.

Populations

Laysan Albatross apparently were never common on Nihoa (see Table 5). The only large estimate--1,000 birds in December 1957 (Kenyon and Rice, 1962: 377)--is certainly erroneous in view of the numbers recorded on other surveys. Evidently Kenyon and Rice confused this species with either Red-footed or Blue-faced Boobies when they made their aerial count, a possibility they themselves suggested.

Direct evidence of breeding has been noted only in March 1915, December 1953, March 1968, and July 1973. The lack of nests on the three other March visits indicates that during some years Laysan Albatross nest unsuccessfully, if at all. No more than 40 birds are known to have nested in any one year but it is possible that a few more may have initiated nests. Rice and Kenyon's estimate of numbers breeding in 1956-1957 is much larger but is erroneous (see Table 5).

Annual Cycle

The data are insufficient to document adequately the periods of arrival, laying, hatching, and fledging. Existing data do not indicate that Laysan Albatross on Nihoa have a cycle any different from that on other northwestern Hawaiian Islands.

Breeding Habitat

Only Munter (1915: 132) and Kridler have given any indication of where nests were found. Munter found a half-grown young about 500 feet up one of the slopes, and in March 1968 Kridler banded four chicks within the Black-footed Albatross colony on Miller Plateau.

Other Areas of Occurrence

Other observers reported pre-breeding or non-breeding birds from several areas. In December 1961, Kramer noted that all Laysan Albatross were on Miller Plateau. In March 1964, BSFW personnel saw most Laysan Albatross on Miller Plateau, but a few were as much as a hundred feet down the south slope of Miller's Peak. In March 1965 Kridler noted that most were on the high ridge between Miller's and Tanager Peaks; in March 1968 these albatross were seen only on Miller Plateau and Tanager Peak.

Banding

Ten Laysan Albatross were banded by the BSFW on recent visits: 6 adults in March 1964 and 4 young in March 1968. No returns have been obtained for these birds.

Table 5. Observations of Laysan Albatross on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Only 1 or 2 seen some miles west of island (Fisher, 1903: 778).
	5-9 Aug.	?	None seen from offshore (Fisher, 1903: 779).
1915	18 Mar.	*ca.* 50 (100)	At least 1 half-grown young seen (Munter, 1915: 132). Alternate estimate by Brown (ms.).
1916	12 Feb.	?	Nesting on Miller Plateau. About as abundant as Black-footed Albatross; 2 pairs seen "near the top of the middle peak" (Munter, ms.).
1923	5 Apr.	?	Many seen in ship's wake offshore (Wetmore, ms.).
	14 June	1	1 adult seen with Black-footed Albatross (Wetmore, ms.).

Table 5. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1936	3 Mar.	?	Evidently nesting (Trempe, ms.).
1940	7-15 Aug.	0	(Vanderbilt and de Schauensee, 1941: 8).
1953	21-22 Dec.	6-8	Breeding in small numbers (Richardson, 1957: 16; pers. comm.).
1954	18 Mar.	0	Only part of island surveyed (Richardson, pers. comm.).
1957	28 Dec.	*ca.* 1,000+	"Nesting" (Rice and Kenyon, 1962: 377).
1961	9-16 Dec.	*ca.* 30	"No eggs. Much bachelor dancing" (Kramer, ms.).
1963	5-6 June	?	None noted offshore (POBSP).
1964	6-7 Mar.	38	Only adults seen. 1 seen on empty nest (BSFW, POBSP).
	25 July	0	(BSFW).
	23-24 Sept.	0	(BSFW, POBSP).
1965	8-9 Mar.	?	One seen from offshore; Miller Plateau not censused (BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	1	No young seen; Miller Plateau not censused (BSFW, POBSP).
	13-14 Sept.	0	(BSFW).
1968	7-9 Mar.	10*	4 young banded on Miller Plateau. 6 adults seen on Tanager Peak; no young found there (BSFW, POBSP).
	24-27 Aug.	0	(BSFW).
1969	21 Mar.	7	Counted. Miller Plateau area not visited (BSFW).

Table 5. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1970	15 Aug.	0	(BSFW).
1971	18-19 Aug.	0	(BSFW).
	15 Sept.	0	(BSFW).
1972	16 Sept.	0	(BSFW).
1973	31 July	40**	20 nearly fledging young counted (BSFW).

* Probable number of breeding birds utilizing island.

** Figure represents a minimum estimate of numbers of birds that bred on the island.

\+ Aerial observations only.

BULWER'S PETREL *Bulweria bulwerii*

Status

Abundant breeder; maximum recent estimate: 250,000. Present from March through September or October; probably absent the rest of the year. Breeds from at least June through September. Nests under rocks, in holes or crevices in rock ledges or occasionally in shallow depressions under dense vegetation.

Populations

None of the numerical estimates (Table 6) is very accurate because of the difficulty of censusing populations of this very numerous petrel. Clearly, however, many thousands are present during July and August.

Annual Cycle

March 1964 and 1965 observations suggest that Bulwer's Petrels begin to return to Nihoa in March but none was observed on a number of other March visits. It seems likely that their reported "absence" in a number of cases may have been the result of simply overlooking small numbers that were present. Descriptions of a bird call heard in March 1967 suggest that Sooty Storm Petrels rather than Bulwer's Petrels were heard on that visit.

Although detailed data on the nesting cycle are scanty, those available suggest that these petrels have much the same cycle on Nihoa as on Laysan and other northwestern Hawaiian Islands. Most birds probably do not arrive at Nihoa until April and eggs probably are not laid until a month or so later. Only eggs were found on two June visits, and only eggs and newly hatched young were found on the two visits in late July and early August. Only young were found from mid-August through mid-September but it seems likely that a few late fledging birds may be present as late as October.

We tentatively assume that the hatching peak occurs in July and early August and that most young fledge about late September.

Breeding Habitat

Several observers noted that this species was found throughout the island but few described the nest sites. Nests were found under rocks, in small holes in the rocks, and particularly in crevices in rock ledges. A few nests were also found in shallow depressions under dense vegetation.

Banding

The POBSP and BSFW banded 808 adults on recent visits: 8 by the BSFW in September 1964 and 800 by the POBSP in July and August 1966. None has been recaptured.

Specimens

Ten Bulwer's Petrel specimens have been collected on Nihoa (Table 7).

Table 6. Observations of Bulwer's Petrels on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1902	1-3 June	?	Abundant offshore. "Birds had been feeding on fish eggs? and ctenophores or comb-jelly" (Fisher, 1903: 795).
	5-9 Aug.	?	Presence noted from offshore (Fisher, 1903: 779).
1923	11-16 June	abundant	Incubating eggs. No nests with young found (Wetmore, ms.).
1940	7-15 Aug.	extremely common	"No eggs were found, all nests examined containing downy, black young" (Vanderbilt and de Schauensee, 1941: 9).
1953	21-22 Dec.	0	Only part of island surveyed (Richardson, pers. comm.).

Table 6. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1954	18 Mar.	0	Only part of island surveyed (Richardson, pers. comm.).
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	0	(Kramer, ms.).
1962	10 June	common*	On eggs (Kramer and Beardsley, ms.).
1963	5-6 June	?	Thousands seen offshore (POBSP).
1964	6-7 Mar.	10	One photographed by Kridler (BSFW, POBSP).
	25 July	very abundant	Many nests found. Only eggs and newly hatched young seen (BSFW).
	23-24 Sept.	1,500	Nearly full grown young and *ca.* 25 dead fledglings seen (BSFW, POBSP).
1966	28 July-1 Aug.	250,000** (225,000)	Mostly on heavily incubated eggs or with *ca.* 1 week old nestlings (BSFW, POBSP). Alternate estimate by Berger (1972: 33).
1967	8-9 Mar.	?	Heard calling in burrows (BSFW, POBSP); see text.
	13-14 Sept.	?	A number of adults and half-feathered young seen but most young evidently departed from island (BSFW).
1968	7-9 Mar.	0?	None seen on island but a few small petrels seen offshore may have been this species (BSFW, POBSP).
	24-27 Aug.	thousands	Hundreds of adults seen during day with numbers increasing to thousands at night. Several downy chicks found (BSFW).
1969	21 Mar.	0	(BSFW).
1970	15 Aug.	75,000-100,000	Burrows examined contained pairs and small downy chicks. Much calling by adults (BSFW).

Table 6. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1971	18-19 Aug.	4,000	Half-grown young seen (BSFW).
	15 Sept.	?	Nearly fully-grown young were common (BSFW).
1972	16 Sept.	?	At least 300 adults seen during day (BSFW).
1973	31 July	?	At least 400 adults seen during day (BSFW).

* In their report Kramer and Beardsley noted that "Bonin Petrels" were common and on eggs. Since no other observer has found that species on Nihoa, and, since Kramer and Beardsley did not mention the presence of Bulwer's Petrel, we assume that "Bonin Petrel" was a *lapsus calimis* for Bulwer's Petrel. Marshall (1964: 160), in a popular account of the visit, also indicates, we think erroneously, that Bonin Petrels were present.

** Most abundant species on island.

Table 7. Bulwer's Petrel Specimens from Nihoa Island.

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and yg.	Museum Nos.	Date Collected	Collector
SUI			1	18597			3 June 1902	Nutting
USNM	2	300799, 530875	1	530876			11-15 June 1923	Wetmore
PAS	3	146160, 146168-69	1	146161			Aug. 1940	Vanderbilt
USNM			1	493022*	1	493023*	6 June 1963	POBSP

* Collected offshore.

WEDGE-TAILED SHEARWATER *Puffinus pacificus*

Status

Abundant breeder; maximum recent estimate: 20,000 to 31,000. Present from March through at least mid-November; most birds probably

absent during remainder of year. Most nesting occurs from June through November. Nests in burrows, on the surface of the ground under thick vegetation, and in cavities and crevices in rock falls and ledges. Well distributed over entire island.

Populations

The few numerical estimates (Table 8) suggest that maximal populations are on the order of tens of thousands rather than hundreds of thousands. In August and September many thousands are present; at dawn the steady chorus of calling results in a dull roar that, at lower elevations, is muffled only by the surf.

Annual Cycle

March observations suggest that these shearwaters return to Nihoa in great numbers within a very short period. In 1964, 1967, and 1968 only a few birds were present in early March, while in 1915 and 1965 thousands were present by the middle of the month. Richardson's lower mid-March estimate does not fit this pattern. However, he did not spend the night on the island and as a result possibly did not see many birds that may have come to the island to roost at night.

The nesting cycle appears to be similar to that found on Laysan and other northwestern Hawaiian Islands. Most egg laying evidently occurs in June although a few eggs may be laid in May. A few young hatch in July but by far the greater proportion hatch in August. It seems likely that most fledge within 5 to 5 1/2 months[26] after the peak of laying. Thus, a few possible fledge as early as late October and as late as early December with the peak being in November. No surveys were made on the island during the presumed fledging period. Kramer observed none in mid-December 1961 (Table 8).

Breeding Habitat

Nests have been found in a wide variety of situations on the slopes of the island. A small proportion of the population digs burrows in the ground but few such burrows are possible because of the shallow soil cover and rocky nature of the island. Wetmore (ms.) noted a number of burrows as much as 3 or 4 feet long but most were only deep enough to provide shelter. A much larger proportion nest in natural cavities in the rocks and on rock ledges protected by overhanging rock. Many others nest on the surface, particularly in areas covered by dense vegetation such as *Chenopodium* or *Sida*.

26/ Based on the range of fledging periods (99-111 days) obtained in a small sample (n = 10) on Kure Atoll (Woodward, 1972: 125) and on an estimated 52 to 54 day incubation period (Woodward, pers. comm.).

Color-Phases

Dark, light, and intermediate plumaged morphs have all been seen on the island. No quantitative data exist on the occurrence of the different color phases but one POBSP observer estimated that 95 percent of the birds were light-phase morphs. Wetmore (ms.) saw gray-breasted birds occasionally, but the great majority was white-breasted.

Banding

The BSFW and POBSP banded 288 adults on recent visits: 3 in March 1964 and 85 in March 1965 by the BSFW, and 200 by the POBSP in July and August 1966. None has been recaptured.

Specimens

We have found records of 8 study skins from Nihoa (Table 9). The USNM houses in addition an embryo alcoholic (USNM 289301) collected by Wetmore on 14 June 1923.

Table 8. Observations of Wedge-tailed Shearwaters on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	A number flew aboard. Stomachs contained the "hard parts of small cephalopods (squid, octopus, and the like)" (Fisher, 1903: 792).
	5-9 Aug.	?	Presence noted (Fisher, 1903: 779).
1915	18 Mar.	"very common"* (50,000)	None found nesting (Munter, 1915: 131). Alternate estimate by Brown (ms.).
1923	24-26 May	?	Thousands seen circling ship (Wetmore, ms.).
	11-16 June	30,000*	Birds laying. Many fresh eggs (Wetmore, ms.).
1936	3 Mar.	?	25 birds, found under clumps of grass and rock, had red celluloid bands placed on their legs (Trempe, ms.).
1940	7-15 Aug.	?*	"Breeding was in its early stages, both eggs and small young being observed" (Vanderbilt and de Schauensee, 1941: 9).

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1953	21-22 Dec.	0	Only part of island surveyed (Richardson, pers. comm.).
1954	18 Mar.	40-60	? (Richardson, pers. comm.).
1961	2 Mar.	?	Not noted offshore (Woodside and Kramer, ms.).
	9-16 Dec.	0	(Kramer, ms.).
1962	10 June	"common"	On eggs (Kramer and Beardsley, ms.).
1963	5-6 June	?	Thousands seen offshore (POBSP).
1964	6-7 Mar.	?	Courting behavior observed (BSFW, POBSP).
	25 July	very common	Several nests with eggs found (BSFW).
	23-24 Sept.	?	*Ca.* 2,000 downy nestlings present (BSFW, POBSP).
1965	13-14 Mar.	18,000	No eggs or young seen (BSFW, POBSP).
1966	28 July-1 Aug.	20,000-31,000	*Ca.* 10,000 nests present, almost all with incubated eggs. One *ca.* 3 week old nestling observed (BSFW, POBSP).
1967	8-9 Mar.	5 (seen)	Apparently vanguard of breeding population (BSFW, POBSP).
	13-14 Sept.	many thousands	Small and large downy chicks (BSFW).
1968	7-9 Mar.	less than 50	No evidence of breeding. Only 2 individuals actually noted (BSFW, POBSP).
	24-27 Aug.	many thousands	So many calling in early dawn hours that combined sound made a low steady roar (BSFW).
1969	21 Mar.	875	Nesting had evidently begun (BSFW).
1970	15 Aug.	20,000-25,000	(BSFW).
1971	18-19 Aug.	?	At least 2,000 birds were present (BSFW).

Table 8. (Continued)

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1971 15 Sept.	?	Active burrows were widespread. Occasional calling was heard (BSFW).
1972 16 Sept.	10,000	(BSFW).
1973 31 July	?	At least 500 birds were seen (BSFW).

* Stated to be most common bird on island.

Table 9. Wedge-tailed Shearwater Specimens from Nihoa Island

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and yg.	Museum Nos.	Date Collected	Collector
USNM	1	189399	2	189400-401			2 June 1902	Fisher
SUI	1	18592					3 June 1902	Nutting
USNM	1	300723	2	300724-725	1	146153	Aug. 1940	Vanderbilt

CHRISTMAS SHEARWATER *Puffinus nativitatis*

Status

Common breeder; maximum recent estimate: 800. Present from at least early March through at least early October; absent remainder of year. Most nesting probably occurs from April through September. Nests most frequently at higher elevations and on the ground.

Populations

Recent numerical estimates made in March and July and August (Table 10) suggest that less than a thousand birds nest on the island. These estimates are of low reliability, however, and it is possible that intensive censusing might reveal greater numbers present.

Annual Cycle

Information that would permit an analysis of the annual cycle is sparse but what is available suggests that this species' cycle

closely parallels, but is earlier than, that of the Wedge-tailed Shearwater. It is not known when these birds begin to return to the island, but most evidently return in early and mid-March. Eggs have been laid as early as late March (1969), but observations made in June and July suggest that most laying probably takes place in April or May. Considerably more detailed information is needed on the nesting status in April and May in order to document adequately the period of peak egg laying. Most eggs evidently hatch in late June and July but at least a few hatch by late May. Some fledging may occur in late August but most probably occurs in September. Judging from the available observations, the number of adults greatly decreases by mid-September, and it seems likely that most have departed by late September.

Breeding Habitat

A number of observers have indicated that this species nests on the higher elevations of the island. Many have recorded nests from such areas. Wetmore (ms.) found a number of pairs on the slopes of Miller's Peak at about 800 to 900 feet. Vanderbilt and de Schauensee (1941: 9) recorded their presence "at the peak of Middle Valley and along the cliff leading to Devil's Slide." Kridler found young among the rocks just below Miller's Peak in July 1964, on the ridge west of Miller's Peak in September 1967, and near Miller's Peak in August 1968. He noted in 1965 that this species was "commonly found at the higher elevations." In July and August 1966 most young were found on the ridges and peaks and along the ledges on the northern rim of the island between Miller's and Tanager Peaks. None was observed on the vegetated slopes of the valleys.

Few data are available on the nature of the nest sites. Wetmore (ms.) reported that Christmas Shearwaters nested "in little shelters beneath overhanging stones or tussocks of grass" where they might or might not be covered.

Banding

Eight adults, none of which has been recaptured, were banded by the BSFW: 1 in March 1964 and 7 in March 1965.

Specimens

Six specimens have been collected on Nihoa. Wetmore collected an adult female (USNM 300699) on 12 June 1923, a juvenile male (USNM 300700) on 14 June 1923, and an embryonic alcoholic (USNM 289399) the same day. The other three specimens (PAS 146165-167), not certainly sexed, were collected in August 1940 by the Vanderbilt Expedition.

Table 10. Observations of Christmas Shearwaters on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted offshore (Munro, 1941a: 49).
1902	1-3 June	?	None seen from offshore (Fisher, 1903: 793).
	5-9 Aug.		A few seen offshore (Fisher, 1903: 793).
1915	18 Mar.	(100,000)	Estimate by Brown (ms.). is most likely erroneous.
1923	11-16 June	0?	*Ca.* 20 pairs found building nests; most birds prelaying or with eggs; one *ca.* 1 week old young found (Wetmore, ms.).
1940	7-15 Aug.	rarest bird on island	"No nests or eggs were observed but one nestling young was seen" (Vanderbilt and de Schauensee, 1941: 9).
1953	18 Mar.	0?	Only part of island surveyed (Richardson, pers. comm.).
	21-22 Dec.	0	Only part of island surveyed (Richardson, pers. comm.).
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	0	(Kramer, ms.).
1962	10 June	very abundant	"On eggs and with downy chicks" (Kramer and Beardsley, ms.).
1963	5-6 June	?	50-100 seen offshore (POBSP).
1964	6-7 Mar.	?	Courting behavior observed. No nests with eggs found (BSFW, POBSP).
	25 July	?	2 young noted. Both were nearly feathered with down remaining only on nape of neck (BSFW).
	23-24 Sept.	0	(BSFW, POBSP).
1965	13-14 Mar.	800	No eggs or young seen (BSFW, POBSP).

231-338 O - 77 - 12

Table 10. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1966	28 July-1 Aug.	500	*Ca*. 250 young, all older than 3 weeks (BSFW, POBSP).
1967	8-9 Mar.	1 seen	Most of breeding population not yet present (BSFW, POBSP).
	13-14 Sept.	10	One young, feathered with down remaining on neck, noted (BSFW).
1968	7-9 Mar.	100	No nests found but 1 pair seen copulating by Kridler (BSFW, POBSP).
	24-27 Aug.	6	3 adults and 3 chicks seen near Miller's Peak. Chicks in juvenile plumage except for scant down on top of head and nape of neck (BSFW).
1969	21 Mar.	50	3 found incubating eggs (BSFW).
1970	15 Aug.	50-100	(BSFW).
1971	18-19 Aug.	40	Downy to near-fledging young seen (BSFW).
	15 Sept.	?	Several seen (BSFW).
1972	16 Sept.	30	(BSFW).

SOOTY STORM PETREL *Oceanodroma tristrami*

Status

Poorly known. Occurs on Nihoa, at least in small numbers, and apparently breeds there.

Observations

The Sooty Storm Petrel has been recorded thrice on Nihoa and once from offshore. Fisher (1903: 795) obtained an immature that retained a trace of down which flew aboard his ship on 1 June 1902. The present location of this specimen is unknown (Vanderbilt and de Schauensee, 1941: 9-10).

On 6 and 7 March 1964 POBSP personnel saw none but heard one calling from a burrow. In addition, they collected two very young

petrel chicks that were found dead. These specimens cannot be located but they were probably young Sooty Storm Petrels since no other species of petrel known to occur on Nihoa would be expected to have chicks at that time of year.

During the visit of 13 to 14 March 1965 Kridler banded one petrel and collected another. In March 1969 Kridler captured and banded two adults which were taken from a burrow about half-way up one of the canyons. Several other petrels were seen in crevices and hollows during this visit.

There are no other definite sightings but observations attributed to Bulwer's Petrel (see that species account) in March 1967 may have referred to this species. In March 1968 several small petrels which could not be positively identified were seen offshore.

This species is the least conspicuous of the petrels breeding in the northwestern Hawaiian Islands. Its call does not carry well and it tends to form localized colonies. Little attempt was made to make nocturnal surveys on some of the recent visits. Thus, if Nihoa has only a small population of these petrels, they could have been easily overlooked.

Banding

The BSFW banded 1 adult in March 1965 and 2 adults in March 1969.

Specimens

We have been unable to discover the location of any of the four specimens mentioned above.

RED-BILLED TROPICBIRD *Phaethon aethereus mesonauta*

Status

Vagrant; one specimen record from June 1923.

Observations

Wetmore collected an immature female (USNM 300997) as it flew over Nihoa on 15 June 1923. The specimen was identified as belonging to the race *P. a. mesonauta* (Clapp and Woodward, 1968: 10-11). (The specimen number was erroneously reported as 300977 in Clapp and Woodward (1968)). This race breeds in the Pacific from the Gulf of California and the Revilla Gigedo Islands to the Galapagos and islands near the coast of Ecuador (AOU, 1957: 27).

The only other specimen record for the central Pacific is one taken in 1968 at French Frigate Shoals (Amerson, 1971: 184). Recent sight records also exist for Johnston Atoll (Moynihan, 1957: 36; Amerson and Shelton, in press).

RED-TAILED TROPICBIRD *Phaethon rubricauda*

Status

Common breeder; maximum recent estimate: 375 to 625. At least small numbers (tens) present in all months, but more numerous from March through September. Known to nest from at least mid-March through at least early October. Nests on ground in shelter or rocks or vegetation.

Populations

Although of low reliability, the various population estimates (Table 11) indicate that less than a thousand tropicbirds breed on Nihoa. Wetmore's May and June 1923 estimate of 800 birds is probably not significantly different from the estimate of 375 to 625 birds made in July and August 1966 due to the low reliability of estimates.

The March 1965 estimate of 400 seems unusually large for that time of year--so large, in fact, that the difference from other years may be significant; possibly more birds initiated nesting earlier than usual. The March 1965 survey was the only recent March survey on which active nests were found.

Annual Cycle

Data are too scanty for detailed analysis of seasonal variation in numbers, but available observations indicate that maximal numbers are present in mid-summer and minimal numbers in mid-winter.

The earliest that eggs were recorded was 3 March and the latest they were recorded was 24 to 25 August. The largest number of eggs are probably present from mid- or late April through June. The presence of eggs in March 1936 and 1965 indicates that hatching those years could have occurred by early May. Most hatching probably occurs in late June and early July.

If the nests initiated in March were successful, young could have fledged by late July. Most fledging likely occurs from late August through September, with at least a few birds fledging in October.

Breeding Habitat

According to most observers, Red-tailed Tropicbirds are widely distributed over the slopes of the island. They are common in rocky crevices at the base of rimrock outcroppings at the west end of the island and in West Palm Canyon, and have been reported as abundant in the vicinity of the cliff face between Miller's and Tanager Peaks. Most nests are in rocky cavities but others are found under overhanging rock ledges. Some nest on the surface of the ground beneath dense vegetation such as *Chenopodium* and *Sida*.

Banding

Seven birds were banded by the POBSP and BSFW in 1964: 4 adults in March by the POBSP and 3 nestlings in September by the BSFW. No returns have been obtained.

Specimens

Two study skins collected by Wetmore in 1923 are apparently all that have been collected on Nihoa. Adult males (USNM 300998-999) were collected on 11 and 12 June; and a skull (USNM 289154) was collected on 15 June.

Table 11. Observations of Red-tailed Tropicbirds on Nihoa

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Several seen displaying from offshore (Munro, 1941a: 50; Palmer *in* Rothschild, 1893-1900: vii-viii).
1902	1-3 June	?	Possibly seen from offshore (Fisher, 1903: 778, 796).
1915	18 Mar.	several	1 pair found nesting (Munter, 1915: 132).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	24-26 May	?	Seen from offshore (Wetmore, ms.).
	11-16 June	800	"Nesting" (Wetmore, ms.).
1936	3 Mar.	?	Nests with eggs found (Trempe, ms.).
1940	7-15 Aug.	fairly numerous	Mostly young nearly full grown but 2 nests with eggs found (Vanderbilt and de Schauensee, 1941: 10).
1953	21-22 Dec.	0	Only part of island surveyed (Richardson, pers. comm.).
1954	18 Mar.	0	Only part of island surveyed (Richardson, pers. comm.).
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	1	Seen flying high over island (Kramer, ms.).

Table 11. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1962	10 June	common	Many with eggs (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca.* 20 seen from offshore (POBSP).
1964	6-7 Mar.	30	Birds at nest sites but no nests with contents (BSFW, POBSP).
	20 July	?	Eggs to nearly grown young (BSFW).
	23-24 Sept.	50	4 large downy young and 5 near-fledging young found (BSFW, POBSP).
1965	13-14 Mar.	400	Eggs but no young present (BSFW, POBSP).
1966	28 July-1 Aug.	*Ca.* 375-625	*Ca.* 100 nests with young; *ca.* 20% about 2-3 weeks old; *ca.* 80% older than 3 weeks (BSFW, POBSP).
1967	8-9 Mar.	20	No eggs or young found (BSFW, POBSP).
	13-14 Sept.	common	A few very large chicks observed (BSFW).
1968	7-9 Mar.	150-200	No nests with contents found. *Ca.* 50 seen in flight over the island at once but no more than 10 found on the ground (BSFW, POBSP).
1968	24-27 Aug.	200-300	From eggs to nearly fledged young. Over 50 nests recorded during course of other activities (BSFW).
1970	15 Aug.	100	Large feathered young noted (BSFW).
1971	18-19 Aug.	200	Young noted were from about 3 weeks old to nearly fledged (BSFW).
	15 Sept.	?	Near-fledging chicks seen (BSFW).
1972	16 Sept.	100	(BSFW).
1973	31 July	150	(BSFW).

BLUE-FACED BOOBY *Sula dactylatra*

Status

Common breeder; maximum recent estimate: 350. Probably present throughout year, but most nesting occurs from February through September or October. Nests on the ground, primarily in areas of higher elevation.

Populations

Recent estimates (Table 12) suggest a maximal population level of 300 to 400 birds. Wetmore's 1923 estimate is reasonably consistent with these estimates but Munter's 1915 estimate is inexplicably higher than recent estimates. Several recent estimates made during summer (1966, 1971) are lower than would be expected, judging from most of the estimates made during March, early in the breeding season. The variability in March and late summer estimates is apparently greater than for estimates from most other northwestern Hawaiian Islands at these times of year, and suggests that the population levels on this island may be more variable from year to year than on other northwestern Hawaiian Islands.

Annual Cycle

Numbers present and numbers breeding are probably considerably lower in late fall and winter but the absence of numerical estimates from these months makes it impossible to determine the degree to which the population varies throughout the year.

Eggs are laid primarily from February through March and at least a few are laid from April through July. In most years apparently little laying occurs in late summer or early fall but the presence of recently fledged young in mid-June 1923 indicates that some egg-laying took place 5 1/2 to 6 months earlier--November or early December. Kramer's observations in December 1961 and June 1962 indicate that some eggs were laid in January or February, and BSFW observations on 21 March 1969 suggest a laying peak about 2 months earlier (late January). Vanderbilt and de Schauensee's observations similarly suggest that laying took place very early in 1940.

Peak numbers of young are probably present from early May through July. Most young evidently fledge from late July through September with a few fledging in October and November.

Breeding Habitat

All observers who noted the location of Blue-faced Booby nests agree that most nests were in open areas (Fig. 24) on the ridges and slopes of the island. On many surveys (1923, 1964, 1965, 1966, 1970, September 1971) the largest concentration of nests or birds

Figure 24. Blue-faced Booby at nest on rocky outcroppings. POBSP photograph, 8 March 1968, by Roger B. Clapp.

was on Miller Plateau. On several surveys (July 1964, July-August 1966, March 1968) a small concentration of nests was located just above the cliff face on the ridge along the north side of the island between Miller's and Tanager Peaks.

In March 1968 a more detailed appraisal of the location of the nests was made. Of the 122 nests counted, 51 (42 percent) were found on Miller Plateau and the upper west slopes of the island; 12 (10 percent) were found on the lower west portion of the island (the area around West and West Palm Valleys); 11 (9 percent) were found on the upper central slopes from the ridge east of Miller Canyon across Middle Valley to the lower slopes of Tanager Peak; 3 (2 percent) were found on the upper east portion of the island (the area around Tanager Peak and the upper portions of East and East Palm Valleys); and 45 (37 percent) were found on the lower eastern slopes of the island (the area around East and East Palm Valleys). In summary, 53 percent were on upper slopes and 47 percent were on lower slopes.

Banding

Nine adults were banded in March 1964 by the POBSP (6) and the BSFW (3), but none has been recaptured. A Blue-faced Booby, banded (USFWS 568-71825) as a "local" at Trig Island, French Frigate Shoals, on 9 June 1967 by POBSP personnel, was found dead (age and sex unknown) at Nihoa on 24 August 1968 (Amerson, 1971: 143, 197, 356).

Specimens

Two adults, a male (USNM 300949) and a female (USNM 300948), were collected by Wetmore 13 June 1923.

Table 12. Observations of Blue-faced Boobies on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Noted as "common" from offshore (Fisher, 1903: 797).
	5-9 Aug.	?	Common; numerous birds in juvenal plumage seen from offshore (Fisher, 1903: 797).
1915	18 Mar.	5,000	Eggs present (Munter, 1915: 131-132). Brown (ms.) gives an identical alternative estimate.
1916	12 Feb.	[apparently not very common]	Some found nesting (Munter, ms.).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	11-16 June	250	Newly-hatched to recently fledged young observed (Wetmore, ms.).
1936	3 Mar.	?	Nesting; eggs noted (Trempe, ms.).
1940	7-15 Aug.	?	"The breeding season had just been completed" (Vanderbilt and de Schauensee, 1941: 10).
1961	2 Mar.	?	Seen on the island from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	very abundant	Birds paired but no nests noted (Kramer, ms.).
1962	10 June	?	Large downy young observed (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca.* 20 seen from offshore (POBSP).

Table 12. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1964	6-7 Mar.	100	*Ca*. 40 active nests found: 90% with eggs, none with young (BSFW, POBSP).
	25 July	?	Nesting (BSFW).
	23-24 Sept.	50	14 immatures counted. No nests with eggs or downy young seen (BSFW, POBSP).
1965	13-14 Mar.	300	Eggs but no young observed. An estimated 150 nests present (BSFW, POBSP).
1966	28 July-1 Aug.	115-140	Sample count of 17 nests: 2 (12%) with heavily incubated eggs, 15 (88%) with 10-21 day old young. 24 immatures also counted (BSFW, POBSP).
1967	8-9 Mar.	2	None found nesting (BSFW, POBSP).
	13-14 Sept.	very common	Downy chicks observed (BSFW).
1968	7-9 Mar.	350	Only eggs present, most probably fresh or slightly incubated. 122 nests counted. Of 77 nests of which the contents are known, 3 (4%) were empty but active and 74 (96%) contained eggs. *Ca*. 300 nesting birds present (BSFW, POBSP).
	24-27 Aug.	200-250	Most abundant on Miller Plateau. Nests there contained eggs to nearly fledged young. Many young fledged (BSFW).
1969	21 Mar.	90*	Eggs to flying young. Most nests with small young (BSFW).
1970	15 Aug.	160	Estimate includes 30 flying young. No dependent young or eggs seen (BSFW).

Table 12. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1971	18-19 Aug.	80*	Most young seen were full grown (BSFW).
	15 Sept.	?	Most birds were on Miller Plateau (BSFW).
1972	16 Sept.	300	At least 75 young were present (BSFW).
1973	31 July	300	(BSFW).

* Estimate is of the number of nesting birds only.

BROWN BOOBY *Sula leucogaster*

Status

Common breeder; maximum recent estimate: 225. Present throughout year with fewer present in winter. Most nesting evidently occurs from February through August but some may occur outside this period. Nests on the ground.

Populations

Recent numerical estimates indicate that peak populations comprise 150 to 225 birds (see Table 13). The estimates from September and December suggest that populations usually decrease during fall and winter. The only early estimate (1923) does not appear significantly different from most recent estimates. The March 1967 estimate is inexplicably small, which may be the result of observer error or possibly indicates a very late nesting season.

Annual Cycle

On Nihoa this species appears to nest earlier than its congener, the Blue-faced Booby. Observations of variously-sized young in March, and Kramer's observations in December 1961, indicate that laying may begin as early as November or December. Most eggs, however, are probably laid in February or March.

The occurrence of a nest with eggs in June (Wetmore, ms.) suggests that an occasional nest is started in May or June and a few nests are probably begun in April. These are possibly renesters.

Observations of the size of young made during the summer suggest that most hatching occurs from about April through May. Most fledging probably occurs from late July through August, with a few birds fledging in September or later; judging from recent observations fledging is largely completed by the end of August.

Breeding Habitat

Brown Booby nests are widely scattered over the slopes of the island and usually are found in locations overlooking rather sharp drops in elevation. Although Brown Booby nests are as restricted to the slopes of the island as are those of the Blue-faced Boobies, nests may often be found along the ridge above the cliff face on the north edge of the island. Some nest sites are possibly on the cliff face itself, but we lack information in this area. In March 1965 most nests were near Tanager Peak and along the western ridge from Miller's Peak to Dog's Head Peak.

In March 1968 we attempted to determine what proportion of the nests was found on Miller Plateau and the upper west slopes of the island; 14 (18 percent) were found on the lower west slopes of the island (in the area around West and West Palm Valleys); 6 (8 percent) were found on the upper west slopes (including Miller Plateau); 6 (8 percent) were found on the upper central slopes and the ridges east of Miller Canyon across Middle Valley to the lower slopes of Tanager Peak; 31 (40 percent) were found on the upper east portion of the island (the area around Tanager Peak and the upper slopes of East and East Palm Valleys; and 20 (26 percent) were found on the lower eastern slopes of East and East Palm Valleys and the surrounding area. In summary, 56 percent were located on upper slopes and 44 percent were on lower slopes.

Banding

The POBSP banded two nestlings, one in March 1964, the other in July 1966. Neither has been recaptured.

Specimens

Two males were collected by Wetmore: USNM 300878 on 14 June 1923, USNM 300880 the following day.

Table 13. Observations of Brown Boobies on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Presence noted from offshore (Fisher, 1903: 779).
	5-9 Aug.	?	Numbers of young birds seen from offshore (Fisher, 1903: 798).
1923	11-16 June	100	Mostly young, many half-grown, but at least 1 nest with eggs present (Wetmore, ms.).
1940	7-15 Aug.	?	"Breeding was in a late stage, and large young were seen on the nests" (Vanderbilt and de schauensee, 1941: 10).
1953	21-22 Dec.	8-10	? (Richardson, pers. comm.).
1957	4 July	?	Two dozen birds followed ship as it passed island (Labrecque, 1957: 19).
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	relatively rare	"Females were on eggs" (Kramer, ms.).
1962	10 June	?	Large downy young observed (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca.* 40 seen from offshore (POBSP).
1964	6-7 Mar.	150-200	*Ca.* 75 nests present, all with eggs except for 1 with a very large nestling (BSFW, POBSP).
	25 July	?	Several nearly fledged and fledged young observed (BSFW).
	23-24 Sept.	20	4 immature birds seen. No nests with eggs or downy young observed (BSFW, POBSP).

Table 13. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1965	13-14 Mar.	150	Eggs and young present. Most nests contained 2 eggs (BSFW, POBSP).
1966	28 July-1 Aug.	40-65	Near end of breeding cycle. *Ca.* 20 immatures on island (BSFW, POBSP).
1967	8-9 Mar.	15	"Nesting" (BSFW, POBSP).
	13-14 Sept.	100	About 50% seen were fledged immatures (BSFW).
1968	7-9 Mar.	225	Fresh eggs to medium-sized downy young. 77 nests counted. Of 38 nests whose contents were checked, 1 (3%) was empty but active; 32 (84%) contained eggs; 1 (3%) held an egg and a naked young; 4 (11%) contained a medium-downy young. *Ca.* 200 nesting birds present (BSFW, POBSP).
	24-27 Aug.	minimum of 50	No nests with eggs or downy young found. Flying immatures seen. 14 seen in one group on Tanager Peak (BSFW).
1969	21 Mar.	110*	Eggs to downy young. Some flying immatures seen.
1970	15 Aug.	135	Very large and fledged young seen (BSFW).
1971	18-19 Aug.	80*	Young from about a month old to fully-fledged birds were present (BSFW).
1972	16 Sept.	150	(BSFW).
1973	31 July	15	(BSFW).

* Estimate is of the number of breeding birds only.

RED-FOOTED BOOBY *Sula sula*

Status

Common breeder; maximum recent estimate: 3,500. Present throughout the year but most abundant in spring and summer. Breeding occurs

throughout year but most of the population breeds from February through October. Builds bulky nests in low bushes or *Pritchardia* palms.

Populations

Recent population estimates (Table 14) consistently indicate maximal populations of 3,000 to 4,000 birds. Surveys made towards the end of the year suggest a consistent decrease in the population, and the one available December estimate suggests that populations decrease markedly, to perhaps one-tenth of the peak.

Wetmore's 1923 estimate is almost twice as large as any recent estimate, but the absence of recent numerical estimates from June, a month when populations may well reach their zenith, precludes any conclusion that populations are smaller today.

Annual Cycle

Our data clearly indicate that laying usually begins in February, with the peak occurring in late February or March. A small downy young about 2 weeks old seen in March 1968 must have come from an egg laid in January, and observations from March 1969 suggest that fairly large numbers of birds laid eggs in January that year. Thus, a few eggs may be laid earlier in the year but the number nesting at this time must represent only a small proportion of the breeding population. Some laying also occurs in May and June but laying thereafter is apparently quite variable from year to year. Observations in July and August 1966 suggest that laying had been largely completed by early July, but observations in September 1967 and 1971 indicate that some laying had occurred in July or August. In September 1964 and August 1970, on the other hand, observations indicate that laying had been completed by late June.

Young are known to have hatched as early as late February and, if eggs observed in the fall were fertile, may have hatched as late as September or October. However, by far the largest proportion of the young probably hatch from May through June or early July.

Little data are available on fledging but a few young may fledge as early as June. (If eggs present in September were fresh, fledging could occur even earlier in the year.) Most probably fledge in August or September, and a very small proportion fledge in October or November.

Thus, breeding probably occurs in all months, but only a few birds breed from late September through early February.

Breeding Habitat

On Nihoa Red-footed Boobies nest on the slopes of the island in small colonies and in widely dispersed individual nests. A large proportion of the nests is found at middle and lower rather than at higher elevations.

A nesting concentration has several times been noted on Miller Plateau (= Albatross Plateau of Venderbilt and de Schauensee, 1941: 10) and in nearby areas. Vanderbilt and de Schauensee noted that they were most abundant there in August 1940 and Kramer stated that the main colony was found on the upper slopes of Miller Valley in December 1961. Kridler found a colony of about 100 nests on the Plateau in July 1964, and considerable numbers were found nesting in that general area in March 1965, July-August 1966, and March 1968. On the latter visit perhaps half the nests were found in the Miller's Peak-Miller Plateau area.

Considerable numbers also nest on slopes of the various valleys, and smaller numbers nest in groves of *Pritchardia* palms. Most nests are built from 3 to 4 feet above the ground in low *Chenopodium*, *Sida* and *Sesbania*.

Color Phases

No quantitative data are available on the proportion of the different color phases in the breeding population but observational data suggest that over 99 percent of the population consists of the white-plumaged morph (Fig. 25). Dark-plumaged morphs have been seen on three occasions. Wetmore (ms.) flushed a "bird in grey plumage with a pure white tail" from a nest with a newly hatched young in June 1923. Another dark-phase bird was noted in March 1964 and still another, evidently paired with a white-phase bird, was noted in March 1968 (Fig. 26).

Banding

Fifty-one adults and 7 nestlings were banded by the BSFW and POBSP on recent visits. Fifty nesting adults were banded by the BSFW in March 1965 and 1 adult and 7 nestlings were banded by the POBSP in July 1966. None has been recaptured.

Specimens

Three specimens were collected by Wetmore: two males (USNM 300912, 300915) on 12 June 1923, and an embryonic alcoholic (USNM 289297) on 14 June 1923.

Table 14. Observations of Red-footed Boobies on Nihoa

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1891 26-27 May	?	Presence noted from offshore. Several captured as they roosted on the ship. An immature seen (Munro, 1941a: 49-50).
1902 1-3 June	plentiful	Seen sitting on nests from offshore (Fisher, 1903: 797).

Figure 25. White-phase plumage morph of the Red-footed Booby, 8 March 1968. POBSP photograph by Roger B. Clapp.

Figure 26. Dark-phase plumage morph of the Red-footed Booby, 8 March 1968. POBSP photograph by Roger B. Clapp.

231-338 O - 77 - 13

Table 14. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1902	5-9 Aug.	?	No adults certainly noted but immatures seen from offshore (Fisher, 1903: 797).
1915	18 Mar.	800 (20,000)	Eggs present (Munter, 1915: 131). Alternative estimate by Brown (ms.) seems much larger than credible.
1916	12 Feb.	?	Mating and building nests. Several fledged young seen (Munter, ms.).
1923	11-16 June	6,000	From recently completed nests through fresh and incubated eggs to recently-hatched through half-grown young (Wetmore, ms.).
1936	3 Mar.	?	Nesting, eggs noted (Trempe, ms.).
1940	7-15 Aug.	?	"Breeding seemed to be in all stages" (Vanderbilt and de Schauensee, 1941: 10).
1953	21-22 Dec.	200-300	? (Richardson, pers. comm.).
1954	18 Mar.	30-40	??? (Richardson, pers. comm.).
1961	2 Mar.	?	Seen on the island from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	?	"All young were nearly full grown and capable of flying" (Kramer, ms.).
1962	10 June	?	Young in various growth stages. No eggs observed (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca.* 80 seen from offshore (POBSP).
1964	6-7 Mar.	2,600	*Ca.* 1,000 nests counted. Of those whose contents were checked, all contained eggs, none young (BSFW, POBSP).
	25 July	?	Eggs to well feathered young but most nests with young (BSFW).
	23-24 Sept.	900	15 large nestlings and 68 immatures counted. No nests with eggs or small young observed (BSFW, POBSP).

Table 14. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1965	13-14 Mar.	3,500*	*Ca.* 1,700 nests counted. All investigated contained eggs. None contained young (BSFW, POBSP).
1966	28 July-1 Aug.	2,800-3,000*	*Ca.* 1,400 nests counted: *ca.* 3-7% with incubated eggs, the rest with young. Of the young about 10% were recently hatched, 40% were about 2-3 weeks old, and 50% were more than 3 weeks old (BSFW, POBSP).
1967	8-9 Mar.	3,000	Only about 5% of nests with eggs, none with young (BSFW, POBSP).
	13-14 Sept.	very abundant	Eggs to near fledging young (BSFW).
1968	7-9 Mar.	3,000	*Ca.* 1,200 nests counted. Eggs to small downy young but most nests with contents had eggs. Sample count of 115 nests: 60 (52%) empty but active; 54 (47%) with eggs; 1(1%) with a small downy young (POBSP, BSFW).
	24-27 Aug.	hundreds	Eggs to flying young. Scattered throughout vegetated slopes of island. Large colony of 150 nests on Miller Plateau (BSFW).
1969	21 Mar.	1,050*	Most nests contained small young but a few held eggs (BSFW).
1970	15 Aug.	1,500	An estimated 500 young present, ranging in size from 3/4 grown to fully fledged. Most young had not yet fledged and no nests with eggs were seen (BSFW).
1971	18-19 Aug.	1,000	Most nests contained near-fledging young but a few nests with eggs were also present (BSFW).
	15 Sept.	?	A few nests contained eggs but most contained young of varying ages (BSFW).
1972	16 Sept.	1,500	Chicks seen (BSFW).
1973	31 July	?	A minimum of 350 birds was present (BSFW).

* Estimate is for the number of nesting birds.

GREAT FRIGATEBIRD *Fregata minor*

Status

Abundant breeder; maximum recent estimate: 10,000. Present throughout year but decidedly less abundant in winter. Some breeding birds present throughout the year but most breeding occurs from February or March through September. Builds bulky nests in low bushes.

Populations

Recent estimates place maximal population levels at about 10,000 (Table 15) but populations may be considerably smaller during late fall and winter. The only two early numerical estimates are not consistent with recent observations. Munter's estimate of 50,000 is much higher than any recent estimate, and Wetmore's estimate of 1,200 is considerably lower than any recent estimate made when a large proportion of the population was breeding. Recent estimates are subject to a degree of error but do not vary from one another enough to support either Munter or Wetmore's estimates.

Annual Cycle

Displaying males have been noted from early December to early June but the earliest that eggs have been known to be laid is about mid-January. The presence of recently hatched young in early March 1965 indicates that some eggs were laid as early as the second week in January. However, the egg-laying peak apparently usually occurs from late February through March with an undetermined number of eggs laid in April, May and perhaps June. Observations from early June 1923 indicate that some egg-laying must have occurred in April, May and June, and the presence of young about a week old in late July 1966 (Fig. 27) predicates laying in late May.

Most hatching probably occurs from April through June and the majority of the young probably fledge from September through October. An occasional bird may fledge as early as late August, and a few as late as November. Dependent immatures have been present in mid-March well into the succeeding nesting season.

Breeding Habitat

Munter (1915: 132) indicated that frigatebirds nested less commonly at high elevations, but most recent observers have found them common on most of the upper two-thirds of the island's slopes.

Vanderbilt and de Schauensee (1941: 10) stated that the "colonies appeared to be limited to localities half-way up most of the valleys." In March 1964 Kridler noted that nests were most abundant near the top of East Palm Valley, Middle Valley, and Miller Canyon, and in September 1967 found them most abundant in the former two areas. In March 1965,

1967, and 1968 these frigatebirds nested most densely on the upper slopes of Miller Valley up to Miller Peak.

On Nihoa these birds nest mostly in many small colonies containing a dozen to 30 nesting pairs, but are also found nesting in widely scattered individual sites. Most nests are placed in low, thick *Chenopodium* and *Sida*.

Banding

The POBSP banded 1 adult and 490 nestlings in July 1966 but none has been recaptured.

Specimens

Two specimens, an adult male (USNM 464440) and an adult female (USNM 464441) were collected on 14 June 1923 by Wetmore.

Table 15. Observations of Great Frigatebirds on Nihoa Island.

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1885	22 July	?	Large downy young (Bishop, 1885a: 2).
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Abundant, seen nesting in bushes from offshore (Fisher, 1903: 799).
	5-9 Aug.	?	"Still to be seen in considerable numbers" [from offshore] (Fisher, 1903: 799).
1915	18 Mar.	50,000	Eggs and males with inflated throat pouches reported (Munter, 1915: 132). Brown (ms.) gives an identical alternative estimate.
1916	12 Feb.	very common	Breeding season apparently just begun but no eggs or young present (Munter, ms.).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	11-16 June	1,200	Incubating eggs or with young from recently hatched to a few half-grown. Only 1 male with inflated throat pouch seen (Wetmore, ms.).
1936	3 Mar.	many	Many nests with eggs (Trempe, ms.).

Table 15. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1940	7-15 Aug.	"Small colonies were quite common"	"The nests contained almost mature young" (Vanderbilt and de Schauensee, 1941: 10).
1953	21-22 Dec.	700-900	? (Richardson, pers. comm.).
1954	18 Mar.	500-1,000	? (Richardson, pers. comm.).
1961	2 Mar.	?	Seen on the island from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	very abundant	Large flying young but no nests with eggs seen (Kramer, ms.).
1962	10 June	?	"Half grown downy young on nests. No males seen in nuptial displays" (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca*. 20 seen from offshore (POBSP).
1964	6-7 Mar.	10,000	*Ca*. 4,800 active nests counted, most with eggs. 10 nests found with recently hatched young; courting birds observed (BSFW, POBSP).
	25 July	?	Downy to well-feathered young but most nests with downy young (BSFW).
	23-24 Sept.	6,000	167 large young counted. *Ca*. 1,000 already fledged young present (BSFW, POBSP).
1965	13-14 Mar.	5,200*	*Ca*. 2,500 nests counted about 70% containing eggs (BSFW, POBSP).
1966	28 July-1 Aug.	4,200-6,900	*Ca*. 2,500 young present, 10% recently hatched, 30% from 2-3 weeks old, and 60% older than 3 weeks old. No nests with eggs observed (BSFW, POBSP).
1967	8-9 Mar.	9,000	Initiating nesting. Of 31 nests checked, 10 (32%) were empty and 21 (68%) contained eggs, 43% of which were fresh and 57% were incubated (BSFW, POBSP).
	13-14 Sept.	very abundant	A few small downy young and many immatures notes (BSFW).

Table 15. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1968	7-9 Mar.	7,000-8,000	Only eggs present. A considerable proportion of population still in prelaying stages (30-40% of males with inflated throat pouches in some areas; 70-80% in others). Sample count of 55 nests: 26 (47%) empty but active, 29 (53%) with eggs. *Ca*. 2,000 nests counted and an estimated 4,000 nesting birds present (BSFW, POBSP).
	24-27 Aug.	?	From half-grown to fledged young (BSFW).
1969	21 Mar.	3,450*	Most nesting birds just beginning to incubate eggs (BSFW).
1970	15 Aug.	4,600	More than 1,100 young were counted. Most were very large and well-feathered but were not yet fledged (BSFW).
1971	18-19 Aug.	?	At least 1,200 present. Most young were about 3/4 grown (BSFW).
	15 Sept.	?	Young were from 1/2 grown to near-fledging size (BSFW).
1972	16 Sept.	3,000*	An estimated 1,500 young were present (BSFW).
1973	31 July	?	At least 2,000 present (BSFW).

* Estimate is for the number of breeding birds only.

PINTAIL *Anas acuta*

Status

Accidental; one record of two birds from September 1971.

Observations

On 15 September 1971 the BSFW survey party saw a female Pintail near a very small puddle of water about one-third of the way up East Palm Valley. The rotting carcass of a drake that had probably been

dead for 2 to 3 weeks was found in the same puddle and a wing (USNM 567292) was collected. Pintails have not previously been recorded from Nihoa but are of fairly regular occurrence on Laysan and Midway Atolls where much more extensive ponds or lagoons are to be found. The species has also been recorded from French Frigate Shoals (Amerson, 1971: 228), Pearl and Hermes Reef (Amerson, Clapp and Wirtz, 1974: 182) and from Lisianski Island (Kridler, unpub. observ.) in the northwestern Hawaiian Islands, as well as from Johnston Atoll (Amerson and Shelton, in press).

GOLDEN PLOVER *Pluvialis dominica*

Status

Uncommon but regular migrant; maximum recent estimate: 50. Recorded in February, March, June, August, September, and December. Largest numbers occurred in March.

Observations

All observations are listed in Table 16.

Specimens

Evidently only one specimen has been collected. The Vanderbilt Expedition obtained a female (PAS 146156) in August 1940.

Table 16. Observations of Golden Plovers on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1902	1-3 June	a few	Seen from offshore (Fisher, 1903: 778).
	5-9 Aug.	a few	Seen from offshore (Fisher, 1903: 779).
1915	18 Mar.	several seen	Seen "on the plateau" (Munter, 1915: 133).
1916	12 Feb.	quite common	(Munter, ms.).
1923	11-16 June	3	Seen on rocks of Adams Bay 11 June (Wetmore, ms.).
1940	7-15 Aug.	a few	"not present in any numbers." Number of dead birds found (Vanderbilt and de Schauensee, 1941: 10).
1953	21-22 Dec.	0	(Richardson, pers. comm.).

Table 16. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1954	18 Mar.	0	(Richardson, pers. comm.).
1961	9-16 Dec.	12	(Kramer, ms.).
1963	5-6 June	1	Seen from offshore (POBSP).
1964	6-7 Mar.	25	(BSFW, POBSP).
	23-24 Sept.	5	(BSFW, POBSP).
1965	13-14 Mar.	50	5 seen near Dog Head Peak (BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	5	(BSFW, POBSP).
	13-14 Sept.	20	(BSFW).
1968	7-9 Mar.	50	Seen in small flocks but more often as individuals. Scattered all over island (BSFW, POBSP).
1968	24-27 Aug.	10-15	Individuals scattered over island (BSFW).
1969	21 Mar.	36	(BSFW).
1970	15 Aug.	2	(BSFW).
1971	18-19 Aug.	0	(BSFW).
	15 Sept.	?	Rare (BSFW).
1972	16 Sept.	1	(BSFW).

BRISTLE-THIGHED CURLEW *Numenius tahitiensis*

Status

Uncommon migrant; five sight records; maximum recent estimate: 5. Recorded in March, August and September.

Observations

Vanderbilt and de Schauensee (1941: 10) reported a small flock of curlews seen "shortly after landing on Nihoa," presumably on 7 August

1940. There are four more recent records. On 13 and 14 September 1967 Kridler saw a single Bristle-thighed Curlew. Two others were seen on rocks about 150 to 200 feet from the base of Miller Canyon 7 to 9 March 1968 (Fig. 28). Another was seen 18-19 August 1971 and five were present on 16 September 1972.

WANDERING TATTLER *Heteroscelus incanus*

Status

Uncommon migrant; maximum recent estimate: 2. Recorded in March, May, June, and August.

Observations

All observations are listed in Table 17.

Specimens

A single specimen was collected by Vanderbilt but we do not know the specific collection data.

Table 17. Observations of Wandering Tattlers on Nihoa Island

Date of Survey		Population Estimate	Observations, Remarks, and References
1923	24 May	2-3	(Wetmore, ms.).
	11-16 June	1-2	Seen daily on rock ledges of Adams Bay (Wetmore, ms.).
1940	7-15 Aug.	very few	(Vanderbilt and de Schauensee, 1941: 11).
1953	21-22 Dec.	1	(Richardson, pers. comm.).
1954	18 Mar.	0	(Richardson, pers. comm.).
1961	9-16 Dec.	0	(Kramer, ms.).
1964	6-7 Mar.	0	(BSFW, POBSP).
	23-24 Sept.	0	(BSFW, POBSP).
1965	13-14 Mar.	0	(BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	2	Along ledges on south side of island (BSFW).
	13-14 Sept.	0	(BSFW).

Figure 27. Nesting Great Frigatebird with downy young in July 1966. BSFW photograph by Eugene Kridler.

Figure 28. Bristle-thighed Curlew foraging among the rocks in lower Miller Valley, 8 March 1968. POBSP photograph by Roger B. Clapp.

Table 17. (Continued)

Date of Survey		Population Estimate	Observations, Remarks, and References
1968	7-9 Mar.	0	(BSFW, POBSP).
	24-27 Aug.	0	(BSFW).
1969	21 Mar.	0	(BSFW).
1970	15 Aug.	1	(BSFW).
1971	18-19 Aug.	1	(BSFW).
	15 Sept.	0	(BSFW).
1972	16 Sept.	0	(BSFW).

RUDDY TURNSTONE *Arenaria interpres*

Status

Common migrant, present in small numbers; maximum recent estimate: 200. Recorded in March, May, June, August, September, and December. Largest numbers occurred in spring (March) and fall (September).

Observations

All observations are listed in Table 18.

Specimens

We know of but one specimen, a female (PAS 146157), collected by the Vanderbilt Expedition in August 1940.

Table 18. Observations of Ruddy Turnstones on Nihoa Island

Date of Survey		Population Estimate	Observations, Remarks, and References
1891	26-27 May	?	2 small flocks seen from offshore (Munro, 1941a: 50).
1902	1-3 June	?	Seen from offshore (Fisher, 1903: 778).
	4-9 Aug.	?	Seen from offshore (Fisher, 1903: 779).
1916	12 Feb.	a few seen	(Munter, ms.).
1923	24 May	2	Seen on ledges below western cliffs (Wetmore, ms.).

Table 18. (Continued)

Date of Survey		Population Estimate	Observations, Remarks, and References
1923	11-16 June	?	"One or two seen daily on the rocks of Adams Bay. Two seen resting on a cairn on Millers Peak 900 feet above the sea" (Wetmore, ms.).
1940	7-15 Aug.	"Probably... most common shorebird."	"Observed in small numbers everywhere, even on the highest peaks." Seen feeding on beetles as well as marine life (Vanderbilt and de Schauensee, 1941: 11).
1953	21-22 Dec.	a few	(Richardson, pers. comm.).
1954	6-7 Mar.	1	(Richardson, pers. comm.).
1961	9-16 Dec.	about 5 seen	(Kramer, ms.).
1963	5-6 June	1	Seen from offshore (POBSP).
1964	6-7 Mar.	10	Seen in gulches and sea cliffs (BSFW, POBSP).
	23-24 Sept.	30-75	(BSFW, POBSP).
1965	13-14 Mar.	100	(BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	75	Flocks of 17, 23, and 32 flying over water on south side of island (BSFW, POBSP).
	13-14 Sept.	75	Scattered small flocks from sea level to the top of the ridge between the peaks (BSFW).
1968	7-9 Mar.	200	Primarily in small flocks or scattered individuals in the lower areas of the island. Common along the rocks at the edge of the surf where a flock of about 28 birds seen bathing. Small flocks of 10-20 birds seen on the crests of some lower ridges (BSFW, POBSP).
	24-27 Aug.	30	Scattered. Most on rock shelf at sea level (BSFW).

Table 18. (Continued)

Date of Survey		Population Estimate	Observations, Remarks, and References
1969	21 Mar.	82	(BSFW).
1970	15 Aug.	8	One seen near the top of Miller's Peak (BSFW).
1971	18-19 Aug.	8	(BSFW).
	15 Sept.	?	Rare (BSFW).
1972	16 Sept.	2	(BSFW).

HERRING GULL *Larus argentatus*

Status

Vagrant; one sight record in March 1965.

Observations

Kridler observed an adult near Derby's Landing on 24 March 1965. Subsequently, while attempting to photograph the bird, Kridler got close enough to make a positive identification. Herring Gulls are one of the several species of gull that occur fairly frequently in the northwestern Hawaiian Islands (Clapp and Woodward, 1968: 26; Sibley and McFarlane, 1968: 314-318). None has been reported previously from Nihoa.

GRAY-BACKED TERN *Sterna lunata*

Status

Abundant breeder; maximum recent estimate: 10,000. Present from February or earlier through September or October; probably absent during remainder of year. Breeds from at least March through September. Nests on the ground, usually in areas of sparse vegetation.

Populations

Recent population estimates and those from 1915 and 1923 agree reasonably well (Table 19) and suggest that maximal populations are about 10,000 birds. Estimates from various March visits are variable, but this may reflect differences in the timing of the breeding cycle from year to year as much as it does any inaccuracies in the estimates themselves.

Annual Cycle

The paucity of observations from January and February makes it impossible to tell when the first birds arrive at the island but the numbers and stage of breeding observed on various March surveys make it obvious that these terns usually arrive at least as early as February.

The initiation of laying apparently varies from year to year. Observations from March 1915, 1964, 1967, and 1968 indicate that the population was just beginning to breed and would probably reach an egg-laying peak later in the month or in April. In March 1965, however, at least several thousand eggs were present by mid-March, suggesting that some laying occurred in February and that the egg laying peak was earlier than on the other March visits. Laying may also occur in May or June but it is not known whether the Gray-backed Terns usually lay in large numbers during these months. Wetmore's 1923 observations indicate a laying peak in early June but the presence of half-grown young at that time shows that at least some eggs had been laid in April.

Hatching may occur from late March or early April through late July but most young probably hatch from about May through early June. The presence of slightly incubated eggs in early March suggests that some young could fledge by early or mid-June but the earliest report of flying young is early August.

Despite the lack of positive observations, it seems likely that most fledging occurs from mid-July through August. Small numbers of young are present on the island in September but by the end of the month almost all young have fledged and most adults have left the island.

Breeding Habitat

Gray-backed Terns are found in much the same areas as are Sooty Terns, but apparently prefer less densely vegetated areas and are much more prone to nest on rock ledges and ridges. Colonies were widely distributed over the slopes of the island (March 1965, July-August 1966, March 1967, 1968), but seem to reach maximum nesting densities in the various canyons and gulches (July-August, 1966; March 1968). On the latter visit they were apparently most abundant in the lower portions of Miller Canyon, Middle Valley, and the lower eastern slopes of the island. Vanderbilt and de Schauensee reported that in August 1940 they occurred in two small colonies, both of them in the upper portion of Middle Valley.

Banding

The BSFW and POBSP banded 119 Gray-backed Terns on recent visits. The BSFW banded 10 adults in March 1964 and 79 adults in March 1965. The POBSP banded 6 adults, 13 flying young, and 11 nestlings in July and August 1966. None has been recaptured.

Specimens

We know of four specimens from Nihoa: Wetmore in 1923 collected an adult male (USNM 300628) on 15 June, a female (USNM 300629) on 12 June, and an embryonic alcoholic (USNM 289312) on 13 June; another male (PAS 145155) was collected by the Vanderbilt Expedition in August 1940.

Table 19. Observations of Gray-backed Terns on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (as "Bridled Tern") (Munro, 1941a: 49).
1902	1-3 June	?	Common; seen from offshore (Fisher, 1903: 781).
	5-9 Aug.	?	Common; seen from offshore. Numbers of flying young seen (Fisher, 1903: 781).
1915	18 Mar.	10,000	"...seen in scattered pairs....Two only were flushed from eggs" (Munter, 1915: 133). Brown (ms.) gives an identical alternative estimate.
1916	12 Feb.	not very numerous	No nests found (Munter, ms.).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	11-16 June	10,000	Majority with fresh eggs but some recently hatched young and a few half-grown young seen (Wetmore, ms.).
1936	3 Mar.	?	No nests found (Trempe, ms.).
1940	7-15 Aug.	?	Found in two small colonies. "Breeding was in its last stages and only young were seen" (Vanderbilt and de Schauensee, 1941: 11).
1953	21-22 Dec.	0	Only part of island surveyed (Richardson, pers. comm.).
1954	18 Mar.	12-14	Only part of island surveyed (Richardson, pers. comm.).
1961	2 Mar.	?	Abundant, seen from offshore (Woodside and Kramer, ms.).

Table 19. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1961	9-16 Dec.	0	(Kramer, ms.).
1962	10 June	?	With eggs and downy young (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca*. 40 seen from offshore (POBSP).
1964	6-7 Mar.	100	*Ca*. 25 nests with eggs observed (BSFW, POBSP).
	25 July	very common	Very small chicks to 2/3-grown young (BSFW).
	23-24 Sept.	50	6 immatures remaining on the island from the preceding season (BSFW, POBSP).
1965	13-14 Mar.	5,000-6,500	Nests contained only eggs. An estimated 2,500 nests present (BSFW, POBSP).
1966	28 July-1 Aug.	8,000*	*Ca*. 4,000 young; 5% recently hatched, 25% from 2-3 weeks old, and 70% older than 3 weeks (BSFW, POBSP).
1967	8-9 Mar.	10,000	On fresh to slightly incubated eggs (BSFW, POBSP).
	13-14 Sept.	very common	Some near fledging young noted (BSFW).
1968	7-9 Mar.	2,000	Only 1 nest with egg found. Most birds evidently pre-nesting (BSFW, POBSP).
	24-27 Aug.	low thousands $<3,000$	A very few 3/4 feathered young but most young flying (BSFW).
1969	21 Mar.	350	? (BSFW).
1970	15 Aug.	6,000	Young ranged in size from about 1/4 grown to fledging. The great majority of birds was near fledging (BSFW).
1971	18-19 Aug.	7,000	Young were from about 1/2 grown to fledging (BSFW).
	15 Sept.	?	Small numbers of near-fledging young were present (BSFW).

231-338 O - 77 - 14

Table 19. (Continued)

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1972 16 Sept.	4,000*	Young were present (BSFW).
1973 31 July	?	At least 1,500 birds were present (BSFW).

* Estimate is of the number of breeding birds only.

SOOTY TERN *Sterna fuscata*

Status

Abundant breeder; maximum recent estimate: 100,000. Usually present from at least mid-February through late September or October but breeds primarily from late February through July or August; probably absent during much of remainder of year. Nests on the ground (Fig. 29), often in areas of dense vegetation.

Populations

Recent population estimates fairly consistently suggest population levels in the low tens of thousands, and do not indicate any difference from estimates made earlier in the 20th century (Table 20). The estimate from March 1965 is considerably higher than any other but it is based on better data. On that visit the portion of the population breeding near Miller's Peak was censused by making a nest density count and applying the density figure to the approximate area covered by nesting birds. (No details on methods employed are available.) That area was estimated to contain about 27,000 breeding birds. This figure, representing only about one-fourth of the total breeding population, is still higher than any other population estimate that has been made on Nihoa. We believe that this datum indicates that many of the other population estimates may have been too low and that total breeding populations are usually 50,000 to 100,000 birds. (Date on the reliability of visual estimates of Sooty Terns, obtained on other islands by the POBSP, suggest that populations of this species are more often underestimated than overestimated.)

Annual Cycle

The initiation of the breeding season may vary by several months from year to year. In at least three years (1915, 1967, 1969) laying evidently began in late February or early March. In 1964, however, the presence of week-old chicks in early March indicates that laying began as early as late January or early February. The presence of young (of unspecified size) in mid-March 1965 and Munter's observations in

February 1916 indicate laying occurred by mid-February in those years. The size of young seen in March 1968 (Table 19) indicates that some egg-laying must have begun by the second or third week of December and continued until the first or second week of January. On the latter visit the distinct hiatus between stages of breeding in different colonies suggested that no eggs were laid in late January or early February. In 1964, 1966, and 1967 only a very small porportion of the breeding population laid before late February, however. Thus, data from five years indicate that the majority of the breeding population begins to lay in late February and early March.

The winter breeding in 1967-1968 probably was an exceptional occurrence as winter breeding populations have not been reported from any of the other northwestern Hawaiian Islands. However, a winter breeding population was reported from Moku Manu in the main Hawaiian Islands (Richardson, 1957: 24).

Some laying occurs in April and May and fresh eggs were reported in June (Wetmore, ms.). Observations made in mid-August 1940 indicate that some eggs were laid as late as mid-July. On Nihoa Sooty Terns have thus exhibited a laying span of about seven months (mid-December to mid-July).

Hatching has occurred from at least January through late August but probably occurs primarily from late March through May. Fledging may occur as early as early March but in most years most fledging probably occurs from late May through July. Fledging possibly occurs as late as October (1940) but is evidently usually completed by August or mid-September.

The absence of breeding birds in late July and early August 1966 is puzzling and may indicate that the population did not breed or that early breeding attempts were entirely unsuccessful. It is also possible that laying began as early as in 1967-1968 and that the breeding season had been completed prior to the survey.

Also puzzling is the paucity of birds in March 1954. Richardson's observations suggest that not only had nesting not begun but that the birds had not begun to return to the island. Clearly, much may yet be discovered about the nature and variability of the Sooty Tern breeding cycle on Nihoa.

Breeding Habitat

Sooty Terns nest in a wide variety of situations on Nihoa but a number of observers noted that they were more common at higher elevations. Munter (1915: 132) found the birds "in ever increasing numbers" as he ascended the slopes. Wetmore (ms.) found them nesting "from the lower rock cliffs clear to the higher summits." He also noted that they occurred in a number of small colonies on the lower slopes but formed larger colonies on the highest slopes. The two colonies reported by

Vanderbilt and de Schauensee (1941: 11) were also found at higher elevations, the larger colony near the top of Middle Valley, the smaller high up in East Palm Valley.

Recent observations confirm that these terns tend to nest in a number of colonies and in larger numbers at higher elevations. In March 1964 BSFW personnel found large colonies on the east slopes of Middle Valley and on Miller Plateau and noted that birds were found nesting elsewhere as well. In July 1964 a large colony was found along the top of the ridge between Miller's and Tanager Peaks, and in March 1965 birds nested there, on Miller Plateau, and on the east slope below Tanager Peak. In March 1968 these birds nested on the slopes at the base of Miller Canyon, near the top of Middle Valley, on the slopes of East Palm Valley, on Miller Plateau, and in a number of other areas. In August 1970 the last few nesting birds were present on the upper slope of the saddle between Miller's and Tanager Peaks.

Most eggs are laid in small depressions on bare ground but are occasionally found on small amounts of dead vegetation. Typically nests are placed beside tufts of grass or under dense vegetation, such as *Chenopodium*, *Sida*, or *Solanum*.

Banding

Two adults were banded by the BSFW in March 1964. Neither has been recaptured.

Specimens

We have found records of five specimens from Nihoa. Four, two adult males (USNM 300548, 300550), an adult female (USNM 300549) and a juvenile female (USNM 300551), were collected by Wetmore between 12 and 15 June 1923. A female (PAS 146154) was collected by the Vanderbilt Expedition in August 1940.

Table 20. Observations of Sooty Terns on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Abundant, seen from offshore (Fisher, 1903: 780).
	5-9 Aug.	?	Abundant, seen from offshore. Many flying young seen (Fisher, 1903: 780).
1915	18 Mar.	20,000 (10,000)	Only eggs found (Munter, 1915). Alternative estimate by Brown (ms.).

Table 20. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1916	12 Feb.	in large numbers	Only eggs found (Munter, ms.).
1923	11-16 June	12,000	Majority of nests with fresh eggs but fledged young present in some parts of colony (Wetmore, ms.).
1936	3 Mar.	?	No nests found (Trempe, ms.).
1940	7-15 Aug.	?	2 colonies, 1 large, 1 small, present. "Nesting was in all stages from unhatched eggs to fully fledged young" (Vanderbilt and de Schauensee, 1941: 11).
1953	21-22 Dec.	15-20	? (Richardson, pers. comm.).
1954	18 Mar.	6-8	? (Richarcson, pers. comm.).
1961	2 Mar.	?	Abundant, seen from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	2	Seen soaring over cliffs (Kramer, ms.).
1962	10 June	?	With eggs and fledged young (Kramer and Beardsley, ms.).
1963	5-6 June	?	Hundreds seen from offshore (POBSP).
1964	6-7 Mar.	10,000-15,000	*Ca.* 6,000 nests with eggs, *ca.* 100 week-old chicks found (BSFW, POBSP).
	25 July	very common	Downy chicks to fledged young (BSFW).
	23-24 Sept.	1	Heard flying overhead. Not breeding (BSFW, POBSO).
1965	13-14 Mar.	100,000	*Ca.* 90% with eggs, 10% with young (BSFW, POBSP).
1966	28 July-1 Aug.	500	Not breeding. 2 groups of birds observed on ground (BSFW, POBSP).
1967	8-9 Mar.	*Ca.* 25,000	On eggs, no young found (BSFW, POBSP).
	13-14 Sept.	?	Only a few adults and flying young noted (BSFW).

Table 20. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1968	7-9 Mar.	*ca.* 20,000	*Ca.* 2,000 to 4,000 nests with fresh to slightly incubated eggs. 2 small colonies with large young also present. 1 contained several hundred young from 1/2 grown (*ca.* 4 weeks old) to near fledging young (*ca.* 6-7 weeks old). The other contained about 50 young (*ca.* 4-5 weeks old). The majority present was not yet nesting (BSFW, POBSP).
	24-27 Aug.	?	? (BSFW).
1969	21 Mar.	6,800	Most incubating eggs; no young seen (BSFW).
1970	15 Aug.	2,000-3,000	A few very large young were still present (BSFW).
1971	18-19 Aug.	1,000	Young were fully feathered (BSFW).
1972	16 Sept.	20	No breeding birds were found (BSFW).
1973	31 July	3,000	(BSFW).

BLUE-GRAY NODDY *Procelsterna cerulea*

Status

Common breeder; maximum recent estimate: 2,500. Present throughout year but evidently more common in spring and summer. Breeds throughout year but majority of birds apparently breeds during spring and early summer. Lays single egg in holes and niches under ledges in cliff faces and rock outcroppings (Fig. 30).

Populations

Most recent estimates and the one made by Wetmore in 1923 suggest that the maximal population level is in the low thousands (Table 21). Considerable variability is found in estimates made at the same time of year but this probably only indicates the low level of reliability of the estimates.

Annual Cycle

Too few detailed observations are available to document completely the breeding cycle; available observations indicate an extended breeding

Figure 29. Sooty Tern incubating egg in lower part of Middle Valley, 9 March 1968. POBSP photograph by Roger B. Clapp.

Figure 30. Blue-gray Noddy chick at nest site in niche in rock wall, 9 March 1968. POBSP photograph by Roger B. Clapp.

season from at least December through October or November in some years (1964, perhaps 1940). In other years (1967, 1968, 1971, 1972) observations from late summer and early fall indicate that nesting had probably been completed by August or September. In March 1964, 1965, and 1968 an estimated 50, 90, and 88 percent, respectively, of the nests contained eggs which suggests a laying peak then or in February. Observations made in December 1953, and reports of variously sized young on a number of March visits (1964, 1965, 1967, 1968), indicate that some laying normally occurs as early as December or January.

Most estimates from late summer and fall (mid-August 1970 and 1971; September 1964, 1967, 1971, 1972) indicate a population decrease at that time which probably means a decrease in the number of breeding birds. More detailed sample nest counts are needed from most seasons to better document the laying peaks and the degree to which breeding activity may diminish during the latter part of the year.

Breeding Habitat

Blue-gray Noddies, like White Terns, nest in considerable abundance on the north rock cliffs of the island but unlike that species nest commonly in various areas on the south slopes of the island. Nests are particularly abundant in niches and cavities in the rock outcroppings just above the shoreline, but many nests are also present on the rock faces and under ledges along the sides of the valleys and in rock outcroppings near the tops of the ridges.

Banding

The BSFW banded 32 Blue-gray Noddies on recent visits: 6 adults in March 1964, 5 adults in March 1965, 2 adults in July 1966, 17 adults and 1 local in March 1968, and 1 adult in August 1968. None has been recaptured.

Specimens

More Blue-gray Noddies have been collected on Nihoa than almost all other species combined--at least 42 specimens. Of these, 33 are located in the National Museum of Natural History, 2 in the Philadelphia Academy of Science, and 7 in the Bernice P. Bishop Museum. A list of these specimens is presented in Table 22.

Table 21. Observations of Blue-gray Noddies on Nihoa Island

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1891 26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1903 1-3 June	?	Abundant; seen from offshore (Fisher, 1903: 781).

Table 21. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1902	5-9 Aug.	?	Abundant; seen from offshore (Fisher, 1903: 779).
1915	18 Mar.	"Several"	2 young birds found (Munter, 1915).
1916	12 Feb.	5-6 seen	A nest with an egg found (Munter, ms.).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	24-26 May	100 noted	Associated in pairs (Wetmore, ms.).
	11-16 June	1,600	From slightly incubated to heavily incubated eggs and from recently hatched to fledged young (Wetmore, ms.).
1936	3 Mar.	?	Presence noted (Trempe, ms.).
1940	7-15 Aug.	rather rare	"Nesting" (Vanderbilt and de Schauensee, 1941: 11).
1953	21-22 Dec.	150-200	"Nesting and laying were apparently just starting" (Richardson, 1957, pers. comm.).
1954	18 Mar.	100-150	? (Richardson, pers. comm.).
1961	2 Mar.	?	Abundant; seen from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	not too common	? "Paired" (Kramer, ms.).
1962	10 June	abundant	"Breeding...one dead chick seen" (Kramer and Beardsley, ms.).
1963	5-6 June	?	Thousands seen from offshore (POBSP).
1964	6-7 Mar.	thousands	From eggs to fledged young found (BSFW, POBSP).
	25 July	fairly common	? (BSFW).
	23-24 Sept.	150-300	Eggs to fledged young (BSFW, POBSP).
1965	13-14 Mar.	500-600	*Ca*. 250 nests, 5% with young (BSFW, POBSP).

Table 21. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1966	28 July-1 Aug.	2,500	? (BSFW, POBSP).
1967	8-9 Mar.	several thousand	From eggs to 1/2 grown young (BSFW, POBSP).
	13-14 Sept.	very common along cliffs	No eggs or young found (BSFW).
1968	7-9 Mar.	2,000	Fresh eggs to near fledging young. Sample count of 34 nests: 30 (88%) with eggs; 3 (9%) with small downy chicks; and 1 (3%) with a near-fledging young (BSFW, POBSP).
	24-27 Aug.	high hundreds <1,000	A special effort made to find nests but no nesting activity noted (BSFW).
1969	21 Mar.	85	? (BSFW).
1970	15 Aug.	75-100	No nests were found (BSFW).
1971	18-19 Aug.	20	(BSFW).
	15 Sept.	0?	None was seen (BSFW).
1972	16 Sept.	50	(BSFW).
1973	31 July	150	(BSFW).

Table 22. Blue-gray Noddy Specimens from Nihoa Island.

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and yg.	Museum Nos.	Date Collected	Collector
USNM	13	300383, 434,436, 437,440, 441,443-450	6	300384-386, 438,442	3	300451-453	12-15 June 1923	Wetmore
USNM	1	289216*	2	289214-215*			12-15 June 1923	Wetmore
USNM					7	289305-308** 323-325***	11,15 June 1923	Wetmore

Table 22. (Continued)

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and yg.	Museum Nos.	Date Collected	Collector
PAS	2	146162, 164					Aug. 1940	Vanderbilt
BPBM					7	4850-852, 7846-850	??	??
USNM	1	493275+					6 June 1963	POBSP

* Skeletons.

** Embryonic alcoholics.

*** Older alcoholics.

\+ Shot from offshore.

BROWN NODDY *Anous stolidus*

Status

Abundant breeder; maximum recent estimate: 20,000. Present throughout the year but most numerous in summer and fall. Breeds throughout the year but in greater numbers from spring through early fall. Builds nest on the ground in both vegetated and open areas (Fig. 31).

Populations

The general trend of estimates (Table 23) shows that birds number at least in the low thousands in summer and fall and that considerably fewer birds are present in March.

The early estimates (1915 and 1923) do not appear to be significantly different from recent estimates, although Wetmore's estimate of 4,000 for June 1923 is a little lower than we would expect, and Brown's estimate for March 1915 is probably erroneously large. The population estimate for July and August 1966 seems particularly large compared with other numerical estimates, but no other estimates have been made at that time of year.

Figure 31. Brown Noddy at nest with egg, March 1967. BSFW photograph by Eugene Kridler.

Annual Cycle

This species shows a less clearly defined breeding cycle than that of any other species breeding in the northwestern Hawaiian Islands. On Nihoa eggs have been laid in all months from December through August and some may have been laid in the other months as well. The more quantitative data suggest that the numbers of laying birds increase considerably during March and several succeeding months, with little laying occurring after mid-August. Observations indicate periods of peak laying as: 1923-June, 1964-July, 1966-June or July, and 1967-late July or early August.

Greatest numbers probably hatch from late June through mid- or late August, and largest numbers probably fledge from late August through October. Judging from data gathered on other northwestern Hawaiian Islands, probably relatively little breeding occurs from November through February.

Breeding Habitat

Brown Noddy nests are widely dispersed over the slopes of the island but tend to be most numerous in ravines. Nests consist primarily of loose aggregations of sticks, weed stems, and straws, and occasionally contain feathers, bones, or pebbles. All nests whose actual locations were reported were found on the ground but the sites varied considerably. Many of the nests were under thick shrubs such as *Chenopodium*, and others were on rock outcroppings, ledges, and in shallow holes in the cliffs.

Banding

In all, 37 Brown Noddies were banded on recent visits to Nihoa: 3 adults by the BSFW in March 1964 and 34 large young by the POBSP in September 1964. None has been recaptured.

Specimens

We have found records of six specimens. Wetmore collected two adult females (USNM 300499-500) on 12 June 1923 and an embryonic alcoholic (USNM 289399) on 14 June. In August 1940 the Vanderbilt Expedition collected two others, a male (PAS 146159) and a doubtfully sexed female (PAS 146158). A third specimen from 1940 is listed by Vanderbilt and de Schauensee (1941: 12) but we do not know its present disposition.

Table 23. Observations of Brown Noddies on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Seen flying offshore and on island (Fisher, 1903: 778-783).
	5-9 Aug.	?	Seen flying offshore and on island (Fisher, 1903: 779-783).
1915	18 Mar.	500 (5,000)	?, no nests noted (Munter, 1915: 133). Alternative estimate by Brown (ms.).
1916	12 Feb.	very numerous	Fresh eggs found. Many young from preceding breeding season seen (Munter, ms.).

Table 23. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1923	11-16 June	4,000	Mostly with fresh or partly incubated eggs (Wetmore, ms.).
1936	3 Mar.	?	No nests found (Trempe, ms.).
1940	7-15 Aug.	extremely plentiful	"Breeding was in all stages" (Vanderbilt and de Schauensee, 1941: 12).
1953	21-22 Dec.	200-250	"a dedinite breeding season had started" (Richardson, 1957 and pers. comm.).
1954	18 Mar.	200-300	? (Richardson, pers. comm.).
1961	9-16 Dec.	?	Eggs and downy chicks (Kramer, ms.).
1962	10 June	?	From eggs to fledged young (Kramer and Beardsley, ms.).
1963	5-6 June	?	Thousands seen from offshore (POBSP).
1964	6-7 Mar.	600	1 nest with eggs and 2 with young found. Courtship behavior observed (BSFW, POBSP).
	25 July	very abundant	Eggs to near-fledging young but *ca.* 99% of nests with eggs (BSFW).
	23-24 Sept.	7,000*	*Ca.* 3,500 young, mostly large chicks or flying immatures. A few nests with eggs or smaller young (BSFW, POBSP).
1965	13-14 Mar.	1,000	90% with eggs, 10% with young (BSFW, POBSP).
1966	28 July-1 Aug.	20,000*	*Ca.* 10,000 nests, 90% with eggs, 10% with young. *Ca.* 75% of young recently hatched, 25% from 2-3 weeks old (BSFW, POBSP).

Table 23. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1967	8-9 Mar.	several thousand	From eggs to 3/4 grown young. Most chicks from 1/3 to 3/4 grown (BSFW, POBSP).
	13-14 Sept.	common	Eggs to flying young but *ca.* 75-80% of nests with small downy chicks (BSFW).
1968	7-9 Mar.	1,000	Fresh eggs to young about 3-4 weeks old. Most of population not nesting (BSFW, POBSP).
	24-27 Aug.	low thousands <5,000	Eggs to flying young (BSFW).
1969	21 Mar.	2,000	Eggs to flying young (BSFW).
1970	15 Aug.	5,000	In a sample of 100 nests, 84 contained eggs, 14 had small downy chicks, and 2 had large near-fledging young. Recently fledged young were also seen (BSFW).
1971	18-19 Aug.	5,000	From eggs to fledged young (BSFW).
	15 Sept.	thousands	(BSFW).
1972	16 Sept.	15,000	(BSFW).
1973	31 July	>4,000	(BSFW).

* Estimate is of number of breeding birds only.

BLACK NODDY *Anous tenuirostris*

Status

Poorly known. Birds probably present throughout the year but changes in population level unknown. Maximum recent estimate: several thousand or low thousands. Only once found breeding (August 1940) but almost certainly breeds on Nihoa every year.

Populations

Virtually nothing is known of the population size since these birds occur primarily on the nearly inaccessible north cliff face, and to a lesser extent on the eastern and western cliff faces. Since the north cliff face cannot be carefully observed, differences in population estimates from survey to survey are nearly meaningless. Estimates (Table 24) indicate that this species is fairly common during the spring.

Annual Cycle

Vanderbilt and de Schauensee (1941: 12) were the only observers who found nests of this species. They noted that this species "nested particularly in Middle Valley." The validity of this observation seems questionable since no other observer has found them nesting in this area. They also noted that there were "no distinct colonies and the bird seemed to mix freely with the...[Brown] Noddy."

Table 24. Observations of Black Noddies on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1891	26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902	1-3 June	?	Presence noted from offshore (Fisher, 1903: 778).
	5-9 Aug.	?	Presence noted from offshore (Fisher, 1903: 779) but the comment that they were seen in August (*loc. cit.*, p. 784) might suggest they were not seen in June.
1923	24 May	?	? (Wetmore, ms.).
	11-16 June	small numbers	Seen in small numbers in the rock shelves below the cliffs on the western side of the island (Wetmore, ms.).
1936	3 Mar.	?	No nests found (Trempe, ms.).
1940	77-15 Aug.	fairly abundant	"Breeding was in all stages" (Vanderbilt and de Schauensee, 1941: 12).
1953	21-22 Dec.	4-8	? (Richardson, pers. comm.).
1954	18 Mar.	2	? (Richardson, pers. comm.).
1961	2 Mar.	?	Not noted from offshore (Woodside and Kramer, ms.).

Table 24. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1961	9-16 Dec.	0	(Kramer, 1961).
1962	10 June	?	? Seen only on cliffs (Kramer and Beardsley, ms.).
1963	5-6 June	?	*Ca.* 100 seen from offshore (POBSP).
1964	6-7 Mar.	*Ca.* 1,000	? (BSFW, POBSP).
	25 July	?	(BSFW).
	23024 Sept.	*Ca.* 250	? (BSFW, POBSP).
1965	13-14 Mar.	700	No eggs or young seen (BSFW, POBSP).
1966	28 July-1 Aug.	6	? (BSFW, POBSP).
1967	8-9 Mar.	several thousand	? (BSFW, POBSP).
1968	7-9 Mar.	at least several hundreds	? No nests found on accessible part of island (BSFW, POBSP).
	24-27 Aug.	?	? Seen in area of northern cliff face (BSFW).
1970	15 Aug.	1,000	(BSFW).
1971	15 Sept.	low thousands	(BSFW).
1972	16 Sept.	1,000	(BSFW).

WHITE TERN *Gygis alba*

Status

Common breeder; maximum recent estimate: 3,000. Present throughout the year but apparently less abundant in fall and winter; probably breeds throughout the year but data are too few to establish when breeding peaks occur. Lays single egg on rock outcroppings and in holes in cliff face.

231-338 O - 77 - 15

Populations

Most recent estimates of the population place it in the low hundreds (Table 25) but these estimates are quite subjective. Since many surveys covered only part of the area where these birds occur most densely, we suspect that many of the estimates are low and that the maximal populations are in the low thousands. Both Munter's and Wetmore's early estimates are considerably larger than any recent estimate, the former so much so that we suspect it was highly inaccurate. Wetmore's estimate is also larger than recent estimates but he may have seen more of the northern cliff face than did observers on more recent trips.

Annual Cycle

Many, if not most, White Terns, nest on the nearly inaccessible north face of the island and many surveys have been unable to find any nests although they were probably present. Consequently we know little about the breeding cycle of this species on Nihoa.

Eggs have been found in March, June, August, and September and pre-fledging young have been found in March, May, June, and August, indicating that laying has occurred in at least February, April, and July. It is likely that at least a small proportion of the population breeds throughout the year.

Breeding Habitat

The great majority of White Terns nests on the sheer cliffs of the north, east, and west sides of the island. A much smaller number nests on the rocky outcroppings of the south slopes of the island. Wetmore (ms.) noted that those on the north cliff face tended to nest below 500 feet and that most nested between 20 and 250 feet above the sea.

Specimens

Four specimens were collected by Wetmore on 13 June 1923: an adult female (USNM 300417), an adult male (USNM 300418) and 2 alcoholics (USNM 289327-328).

Table 25. Observations of White Terns on Nihoa Island

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1891 26-27 May	?	Presence noted from offshore (Munro, 1941a: 49).
1902 1-3 June	?	Common; seen from offshore (Fisher, 1903: 785-786).

Table 25. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1902	5-9 Aug.	?	Common; seen from offshore (Fisher, 1903: 785-786).
1915	18 Mar.	50,000 (100,000)	? (Munter, 1915: 133). Alternative estimate by Brown (ms.).
1916	12 Feb.	seen occasionally	Stated to be not as numerous as on the March, 1915, survey (Munter, ms.).
1923	5 Apr.	?	Occasionally seen offshore (Wetmore, ms.).
	24-27 May	abundant	Eggs and young found (Wetmore, ms.).
	11-16 June	8,000	Some beginning to breed; "other seemed to have young" (Wetmore, ms.).
1936	3 Mar.	?	No nests found (Trempe, ms.).
1940	7-15 Aug.	not particularly abundant	"Breeding was in an early stage, the eggs just commencing to hatch" (Vanderbilt and de Schauensee, 1941: 12).
1953	21-22 Dec.	20-30	? (Richardson, pers. comm.).
1954	18 Mar.	20-30	? (Richardson, pers. comm.).
1961	2 Mar.	?	Abundant; seen from offshore (Woodside and Kramer, ms.).
	9-16 Dec.	?	"Many flying immatures seen" (Kramer, ms.).
1963	5-6 June	?	Thousands seen from offshore, including many young birds (POBSP).
1964	6-7 Mar.	thousands	Eggs to fledged young (BSFW, POBSP).
	25 July	?	(BSFW).
	23-24 Sept.	350	Eggs to fledged young (BSFW, POBSP).
1965	13-14 Mar.	800	? No attempt made to look for nests (BSFW, POBSP).
1966	28 July-1 Aug.	500	? (BSFW, POBSP).

Table 25. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1967	8-9 Mar.	600	? (BSFW, POBSP).
	13-14 Sept.	?	One found incubating an egg (BSFW).
1968	7-9 Mar.	many hundreds	? No nests found on accessible part of island (BSFW, POBSP).
	24-27 Aug.	many hundreds	Eggs to flying young (BSFW).
1961	21 Mar.	30	? (BSFW).
1970	15 Aug.	100-200	(BSFW).
1971	18-19 Aug.	3,000	Near fledging young seen (BSFW).
1972	16 Sept.	300	(BSFW).
1973	31 July	2,000	(BSFW).

MOCKINGBIRD

Status *Mimus polyglottos*

Vagrant; one sight record in August 1971.

Observations

Robert J. Shallenberger observed and photographed a Mockingbird that he saw on Miller Plateau during the BSFW survey of 18-19 August 1971. The species has not been recorded previously from Nihoa but is well established in the main Hawaiian Islands and has previously wandered to both French Frigate Shoals and Necker Island in the northwestern Hawaiian Islands (Amerson, 1971: 302; Berger, 1972: 215).

NIHOA MILLERBIRD *Acrocephalus familiaris kingi*

Status

Common endemic breeder; maximum recent population estimate: 625. Present throughout the year but infrequently seen because of its tendency to skulk in dense shrubbery. Nests in low bushes and probably breeds from at least February through late August or early September.

Populations

Recent population estimates, based primarily on transect censuses, have varied widely (Table 26) but this variation is more likely attributed to inadequacies of the censuses than to very marked changes in the populations of Millerbirds. In any case it seems likely that the population consists of at least several hundred birds.

Annual Cycle

Little is known of the reproductive habits of the Nihoa Millerbird since only four active nests had been found through July 1973 (Table 26). What little evidence is available suggests that the species nests primarily during the northern hemisphere spring and summer.

Breeding Habitat

This species occurs widely throughout the island but seems to prefer areas of dense *Sida* and *Chenopodium*. Berger (1972: 110) has pointed out that of all nests found to date, two were in *Sida* and the rest were in *Chenopodium*. Berger (*op. cit.*: 110) has described old nests seen by him as averaging "about 3 by 4 inches in maximum diameter and were composed primarily of strips and pieces of grass stems and blades, with varying amounts of rootlets. All of the nests contained some feathers of other species of birds, white being the predominant color used."

Banding

Thirty-two Millerbirds have been banded on Nihoa by the BSFW: 8 in September 1964, 1 in March 1965, March 1967, March 1968, 4 in August 1968 and 17 in June 1969.

Specimens

We know of 26 study skins of the Millerbird from Nihoa Island. These are listed in Table 27. There are, in addition, a skeleton (USNM 289276) and an alcoholic (USNM 289299), both collected by Alexander Wetmore in June 1923.

Table 26. Observations of Nihoa Millerbirds on Nihoa Island

Date of Survey	Population Estimate	Breeding Status, Remarks, and References
1923 11-16 June	near 100	Described as a new species *Conopoderas kingi* by Wetmore (1924). The breeding season had ended and young were fully grown.
1940 7-15 Aug.	?	No nests or young birds seen (Vanderbilt and de Schauensee, 1941: 13).
1953 21-22 Dec.	?	Only two individuals seen (Richardson, 1954: 224).

Table 26. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1961	9-16 Dec.	200	"Pairing appeared to be taking place" (Kramer, ms.).
1962	10 June	?	Many males singing. One nest containing one egg was found (Kramer and Beardsley, ms.).
1964	6-7 Mar.	?	7 birds seen. No nests found (POBSP, BSFW).
	25 July	?	3 birds seen, 2 of which appeared to be paired (BSFW).
	23-24 Sept.	150	No evidence of nesting found (POBSP, BSFW).
1965	13-14 Mar.	100-150	No nests found (BSFW, POBSP).
1966	28 July-1 Aug.	150	Six old nests found 1 August (Berger, 1972: 110).
1967	8-9 Mar.	?	Ten to 15 birds seen. Some singing males heard (POBSP, BSFW).
	13-14 Sept.	625	Estimate based on transect censuses (BSFW).
1968	7-9 Mar.	615	Estimate based on transect censuses. No nests found but a recently fledged young observed (POBSP, BSFW).
	24-27 Aug.	?	A nest with two eggs found 25 August (Berger, 1972: 1101.
1969	21 Mar.	41 (0-123)*	Based on transect censuses. No evidence of nesting was found (BSFW).
	29 May-10 June	498 (211-785)*; 493 (285-701)*	1st estimate based on transect censuses 30 May; 2nd estimate based on transect censuses 6 June (BSFW). A nest with two small young found 30 May and one with a near fledging young found 2 June (Berger, 1972: 110).
1970	15 Aug.	384 (134-477)*	Based on transect censuses. No nests found (BSFW).

Table 26. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
1971	18-19 Aug.	273 (91-454)*	Based on transect censuses (BSFW).
	15 Sept.	?	About 10 birds seen (BSFW).
1972	16 Sept.	592 (334-850)*	Based on transect censuses (BSFW).
1973	31 July	198 (46-350)*	Based on transect censuses (BSFW).

* Figures in parentheses represent confidence limits for the population estimate at a 95% confidence level.

Table 27. Nihoa Millerbird specimens from Nihoa Island

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and imm.	Museum Nos.	Date Collected	Collector
USNM	5	287888 (type), 301126, 301138-140	1	301127	10	301128-137	12-15 June 1923	Wetmore
PAS	4	146144-145, 146149, 146152	5	146143, 146146-148, 146150			16 Aug. 1940	Vanderbilt
AMNH					1	325832	16 Aug. 1940	Vanderbilt

NIHOA FINCH *Psittarostra cantans ultima*

Status

Abundant endemic breeder; maximum recent population estimate: 6,686. Present throughout the year. Commonly seen because of their confiding nature. Prefers to nest in rocky outcroppings and nests principally from late February through at least April.

Populations

Although recent estimates are variable, they suggest a population on the order of 3,000 to 5,000 birds (Table 28). These estimates are consistently higher than those estimates made by earlier observers but we believe that this difference may be attributed to more reliable recent estimation techniques than to any inherent change in the population levels of this finch. Recent estimates do not suggest any pronounced seasonal changes in populations.

Annual Cycle

Available evidence suggests a fairly pronounced spring breeding season. A near fledging young seen by Richardson on 18 March 1954 indicates that egg-laying may begin in late February. This is corroborated by the presenceof young early in March during 1967 and 1969. No data is available for nesting activities during April and nests have not been recorded later in the year. Observations by Berger (1972: 159-161) on captive Nohia Finches may suggest the potential extent of the breeding season in the wild. He recorded eggs during a period extending from 17 December 1969 through 27 July 1970.

Breeding Habitat

Nihoa Finches are widespread over the island but often occur commonly near the rocky outcroppings (Fig. 32) which serve as their principal nesting sites. Several observers have noted that these birds often congregate near seeps or pools of water with Wetmore noting that as many as 50 could be seen in such situation at one time.

Figure 32. Nihoa Finch on rocky outcropping, 16 September 1972. BSFW photograph by Eugene Kridler.

Food Habits

Like the related subspecies on Laysan Island, Nihoa Finches are avid egg eaters, a behaviorism that has been recorded by many observers. In 1923 Wetmore noted that literally thousands of tern, shearwater, and petrel eggs had had their sides cut open by the finches. In July and August 1966 both Berger (1972: 157) and Heiden (POBSP) noted this species feeding on eggs of the Brown Noddy. In one instance Berger noted 20 finches within 30 feet of a single broken egg. Heiden also observed this species feeding on the eggs of the Gray-backed Tern, Red-footed Booby, and Wedge-tailed Shearwater.

The only other information available on the food habits of this species comes from Vanderbilt and de Schauensee (1941: 13) and Richardson (1954: 224). The former noted that several stomachs contained "...a gelatinous yellow substance (probably yolk of egg), minute black seeds and microscopic pebbles." Richardson repeatedly observed these finches "eating the small, green flower heads of *Chenopodium sandwicheum*...[and noted]...one bird picking out the still partly green seed of *Portulaca caumii*".

Banding

A total of 336 Nihoa Finches have been banded by the BSFW. Four adults were banded in September 1964; 8 nestlings were banded in March 1965; 12 adults were banded in July 1966; 46, all adults except for one immature, were banded in March 1967; 22 nestlings were banded in March 1968; 37, including 7 adults and 30 immatures were banded in August 1968, and another 207 were banded in June 1969. Forty-five of the 46 birds banded in March 1967 were shipped by BSFW to French Frigate Shoals with 32 later being introduced to Tern Island and with 10 being introduced to East Island. The East Island population did not survive. As many as 9 were still present on Tern Island in September 1971 (BSFW).

Specimens

Fifty-nine specimens of Nihoa Finches are listed by location in Table 29. There are in addition a skeleton (USNM 289277) and an alcoholic (USNM 289329) both of which were collected by Wetmore in June 1923.

Table 28. Observations of Nihoa Finches on Nihoa Island

Date of Survey		Population Estimate	Breeding Status, Remarks and References
1885	22 July	?	Species seen by Sanford B. Dole (Munro, 1960: 130).
1915	18 Mar.	"1,000 or more"	(Munter, 1915: 132). The presence of this bird was later noted by Bryan (1916).
1916	12 Feb.	?	5 specimens collected by Munter (ms.) were later described as a new species *Telespiza ultima* by Bryan (1917).
1923	11-16 June	800	Birds had finished breeding and adults were in molt (Wetmore, ms.).
1940	7-15 Aug.	500-1,000	Birds not nesting but 2 old nests found (Vanderbilt and de Schauensee, 1941: 13).
1953	21-22 Dec.	"reasonably numerous"	2 old nests found (Richardson, 1954: 224).
1954	18 Mar.	-	1 near-fledging young found in 1 of the nests seen the previous December (Richardson, 1954: 224).
1961	9-16 Dec.	800-1,200	No nests found (Kramer, ms.).
1962	10 June	"as abundant as in December 1961"	No nests found (Kramer and Beardsley, ms.).
1964	6-7 Mar.	2,500-5,000	1 bird seen nest building (POBSP).
	23-24 Sept.	4,500-5,000	No evidence of nesting found (POBSP, BSFW).
1965	13-14 Mar.	4,000	6 nests with young and 1 containing 3 eggs found. Of 4 nests examined, 2 contained 2 young and 2 contained 3 young. 8 nestlings were banded (POBSP, BSFW).
1966	28 July-1 Aug.	5,000	No evidence of breeding found (POBSP, BSFW).
1967	8-9 Mar.	5,000	42 birds captured for introduction to Tern and East Islands, French Frigate Shoals (POBSP, BSFW). Eggs and young found (Berger, 1972: 158).

Table 28. (Continued)

Date of Survey		Population Estimate	Breeding Status, Remarks, and References
	13-14 Sept.	5,000	Estimate based on transect censuses (BSFW).
1968	7-9 Mar.	6,600	Estimate based on transect censuses. Birds apparently at a peak of nesting. Birds seen building. 13 nests found with a total of 28 nestlings and 10 eggs. The maximum number of young in a nest was 4. 22 nestlings were banded (POBSP, BSFW).
	24-27 Aug.	6,686 (4,881-8,491)*	Estimate based on transect census (BSFW).
1969	21 Mar.	2,993 (1,913-4,073)*	Estimate based on small number of transect censuses and possibly subject to error. 2 nests found, 1 with 1 egg and 1 with 1 young (BSFW).
	29 May	2,987 (2,206-3,948)* 1,528 (924-2,132)*	1st estimate based on transect censuses 30 May; 2nd estimate based on transect censuses 6 June (BSFW).
1970	15 Aug.	2,341 (1,637-3,045)*	Estimate based on transect censuses. Several old nests found; no evidence of breeding noted (BSFW).
1971	18-19 Aug.	3,759 (2,707-4,811)*	Estimate based on transect censuses. No active nests found (BSFW).
	15 Sept.	common everywhere	(BSFW).
1972	16 Sept.	3,799 (3,009-4,589)*	Estimate based on transect censuses (BSFW).
1973	31 July	1,318 (892-1,744)*	Estimate based on transect censuses (BSFW).

* Figures in parentheses represent confidence limits for the population estimate at a 95% confidence level.

Table 29. Nihoa Finch specimens from Nihoa Island

Museum	Males	Museum Nos.	Females	Museum Nos.	?? and imm.	Museum Nos.	Date Collected	Collector
BPBM?					1*		12 Feb. 1916	Munter
LACM	2	20243 (holotype) 20244 (paratype)	1	20244 (paratype)	1	20246 (paratype)	12 Feb. 1916	Munter
USNM	10	301144,301147, 301150,301159 301167,301171** 301174-177	5	301148,301160-161,301170**, 301180	26	301145,301146, 301149,301151-154,301156**, 301157-158, 301162-169, 301172-173, 301178-179, 301181-184	11-15 June 1923	Wetmore
PAS	3	146136,146138-139	1	146141	6	146133-135, 146137-140, 146142	16 Aug. 1940	Vanderbilt
AMNH					1	325831	16 Aug. 1940	Vanderbilt
USNM	1	531868					8 Mar. 1967	Kridler
USNM			1	531869			15 Sept. 1967	Kridler

* One of the original five specimens preserved in spirits and may still be in the Bishop Museum.

** This bird was later exchanged to the Museum of Comparative Zoology.

Mammals

Only one species of mammal is known to occur at Nihoa and its appearance there is uncommon.

HAWAIIAN MONK SEAL *Monachus schauinslandi*

Status

Uncommon visitor. Not known to breed at Nihoa.

Observations

All observations of this species at Nihoa are summarized in Table 30.

Table 30. Observations of Hawaiian Monk Seals at Nihoa Island

Date of Survey		Number Seen	Remarks and References
1857	23 Apr.	about a dozen	On beach. Several shot by King Kamehameha IV (Paty *in* Emory, 1928: 9).
1940	7-15 Aug.	0	(Vanderbilt and de Schauensee, 1941: 8).
1953	21-22 Dec.	0	(Kenyon and Rice, 1959: 217).
1954	18 Mar.	0	(Kenyon and Rice, 1959: 217).
1957	28 Dec.	0	(Rice, 1960: 377).
1964	6-7 Mar.	1	1 lying on small beach on west side of Adam's Bay 6 March. Adult seem swimming offshore later in day (POBSP).
	23-24 Sept.	1	Adult swimming near landing site (BSFW, POBSP).
1965	13-14 Mar.	6	3 seen each day: 2 adults, male and female; 4 subadults, 1 female (BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW, POBSP).
1967	8-9 Mar.	0	(BSFW, POBSP).
	13-14 Sept.	0	(BSFW).

Table 30. (Continued)

Date of Survey		Number Seen	Remarks and References
1968	7-9 Mar.	0	(BSFW, POBSP).
	24-27 Aug.	0	(BSFW).
1969	21 Mar.	0	(BSFW).
	29 May	1	(BSFW).
1970	15 Aug.	0	(BSFW).
1971	18-19 Aug.	0	(BSFW).
	15 Sept.	1	Found basking on sandy beach (BSFW).
1972	16 Sept.	3	(BSFW).
1973	31 July	4	Basking on sandy beach (BSFW).

Reptiles

Two species of reptiles, a lizard and a turtle, are known to occur at Nihoa. Both are uncommon and there is no adequate evidence that either species has ever bred there.

MOURNING GECKO *Lepidodactylus lugubris*

Status

Uncommon resident; probably a recent introduction that may not be established.

Observations

This species has only been twice seen on Nihoa. A single specimen was collected in *Eragrostis* clumps in September 1964 (Beardsley, 1966: 160) and another specimen was collected in March 1965 by Walker. The absence of observations from earlier visits, particularly those in 1923 and 1940, suggests that the species is probably a recent introduction, most likely stemming from 1961 and 1962 when oil barrels, boards, and much other miscellaneous material was ferried to the island by the helicopters of the HIRAN operation. The absence of more recent observations suggests that the gecko may not have become established on the island.

GREEN TURTLE *Chelonia mydas*

Status

Uncommon visitor.

Observations

Emory (1928: 8) remarked that "Turtles are fairly common [at Nihoa]" but we have been unable to find any historical basis for his statement. Perhaps some were seen during his visit in 1924. Recent observations of turtles at Nihoa are few (Table 31) and indicate the species is only an occasional visitor to the island. They are most likely visitors from the nearby large breeding colony at French Frigate Shoals (see Amerson, 1971: 79-92).

Table 31. Observations of Green Turtles at Nihoa Island

Date of Survey		Number Seen	Remarks and References
1964	6-7 Mar.	0	(BSFW, POBSP).
	23-24 Sept.	2	Seen just offshore (BSFW, POBSP).
1965	13-14 Mar.	1	About 2 1/2 feet long (BSFW, POBSP).
1966	28 July-1 Aug.	0	(BSFW).
1967	8-9 Mar.	1	1 large turtle seen offshore on 9 March (BSFW, POBSP).

Table 31. (Continued)

Date of Survey		Number Seen	Remarks and References
1967	13-14 Sept.	0	(BSFW).
1968	7-9 Mar.	1	Seen swimming offshore on 8 March (BSFW, POBSP).
	24-27 Aug.	0	(BSFW).
1969	21 Mar.	0	(BSFW).
1970	15 Aug.	0	(BSFW).
1971	18-19 Aug.	0	(BSFW).
	15 Sept.	3	2 were on a low rock at the base of the northwest cliff; the other was seen swimming around the ship (BSFW).
1972	16 Sept.	1	(BSFW).
1973	31 July	0	(BSFW).

ACKNOWLEDGMENTS

Many persons contributed much time and effort towards the completion of this report. Michio Takata, Director, Hawaii Division of Fish and Game, kindly allowed us to use unpublished reports in the Division's files. Dr. Alexander Wetmore, Smithsonian Institution, Washington, D.C., graciously gave us full use of the information obtained by him during the 1923 Tanager Expedition, and Dr. Frank Richardson, University of Washington, Seattle, Washington, communicated population estimates made during his visits to the island in December 1963 and March 1964. Mr. Edwin H. Bryan, Jr., Manager of the Pacific Science Information Center of the Bernice P. Bishop Museum, Honolulu, aided by allowing us full access to his files on many different occasions. Dr. Philip S. Humphrey, University of Kansas, Kansas, principal investigator of the POBSP, is to be thanked for his constant support during the many frustrations encountered during the preparation of this account.

Many others, particularly personnel of the Pacific Ocean Biological Survey Program, Bureau of Sport Fisheries and Wildlife, and Hawaii Division of Fish and Game, contributed field data which constitute a large proportion of the information presented herein. These persons are listed in Appendix Table 1.

We also thank A. Binion Amerson, Jr., and Dr. Philip C. Shelton who made valuable comments during the preparation of the manuscript. Dr. F. Raymond Fosberg kindly read and commented on the vegetation section of this report. A. Binion Amerson critically read the entire final draft.

Field work on Nihoa was made possible by a cooperative agreement between the Department of the Interior, Bureau of Sport Fisheries and Wildlife, and the Smithsonian Institution. We are also most grateful to the U.S. Coast Guard whose logistic support made possible most of the visits to Nihoa.

The camera copy was typed by Barbara B. Anderson with funding through a contract with the Bureau of Sport Fisheries and Wildlife, Department of the Interior (contract number 14-16-008-596, February 3, 1971).

231-338 O - 77 - 16

LITERATURE CITED

Agassiz, A., and H.L. Clark. 1907-1912. Hawaiian and other Pacific Echini. Mus. Comp. Zool. Harvard, Mem. 34: vii + 383 pp.

Alexander, W.B., *et al.* 1965. The families and genera of petrels and their names. Ibis 107: 401-405.

Amerson, A.B., Jr. 1968. Tick distribution in the central Pacific as influenced by seabird movement. J. Med. Ent. 53(3): 332-339.

-----1971. The natural history of French Frigate Shoals, northwestern Hawaiian Islands. Atoll Res. Bull. 150: xv + 383 pp.

Amerson, A.B., Jr., R.B. Clapp, and W.O. Wirtz II. 1974. The natural history of Pearl and Hermes Reef, northwestern Hawaiian Islands. Atoll Res. Bull. 174: xiv + 306 pp.

Amerson, A.B., Jr, and P.C. Shelton. In press. The natural history of Johnston Atoll, central Pacific Ocean. Atoll Res. Bull. 192: 1-498.

Anonymous. 1920. A South Sea bird island north of the equator. Mid-Pac. Mag. 19: 559-561.

A.O.U. [American Ornithologists' Union]. 1957. Checklist of North American Birds, 5th ed. Lord Baltimore Press, Baltimore. xii + 691 pp.

-----Committee on Classification and Nomenclature. 1973. Thirty-second supplement to the American Ornithologists' Union check list of North American Birds. Auk 90: 411-419.

Ball, S.C. (ms.). Field notebook kept during the 1923 Tanager Expedition. B.P. Bishop Museum, Honolulu.

Baylis, J.S. (ms.). Cruise report for the ITASCA for the month of June 1934. Rec. Group 26, U.S. Nat. Archives, Washington, 6 pp.

Beardsley, J.W. 1966. Insects and other terrestrial arthropods from the leeward Hawaiian Islands. Proc. Haw. Ent. Soc. 19: 157-185.

Berger, A.J. 1972. Hawaiian birdlife. Univ. of Hawaii Press, Honolulu. xii + 270 pp.

Beccari, O. 1889. Le palme del genere *Pritchardia*. Malesia 3: 281-317.

Beccari, O., and J.F. Rock. 1921. A monographic study of the genus *Pritchardia*. B.P. Bishop Mus. Mem. 8: 1-77.

Bishop, S.E. 1885a. Geological and topographical report upon Nihoa or Bird Island, surveyed July 22, 1885. Hawaiian Government Survey, Honolulu. 7 pp.

-----1885b. Nihoa--its topography, something about its geology. Honolulu. 7 pp.

Brown, J.H. (ms.). Report to the Captain Commandant of the Coast Guard of observations made during a cruise to Laysan, Lisianski, etc. in March 1915. Rec. Group 26, U.S. Nat. Archives, Washington. 14 pp.

Bryan, E.H., Jr. 1942. American Polynesia and the Hawaiian Chain. Tongg Publ. Co., Honolulu. 253 pp.

Bryan, E.H., Jr., *et al.* 1926. Insects of Hawaii, Johnston Island and Wake Island. B.P. Bishop Mus. Bull. 31: 1-94.

Bryan, W.A. 1916. An undescribed species of Drepanididae on Nihoa, Hawaiian Group. Auk 33: 49-52.

-----1917. Description of *Telespiza ultima* from Nihoa Island. Auk 34: 70-72.

Buck, P.H. 1953. Explorers of the Pacific. B.P. Bishop Mus. Spec. Publ. 43: 1-125.

BSFW [Bureau of Sport Fisheries and Wildlife]. U.S. Fish and Wildlife Service, Kailua, Hawaii [unpublished reports and notes].

Kridler, E. [1964]. Hawaiian Islands National Wildlife Refuge ...[survey]..., July 25-27, 1964. 8 pp.

-----[1964]. Hawaiian Islands National Wildlife Refuge...[survey] ..., September 16 through 27, 1964. 30 pp.

-----[1965]. Hawaiian Islands National Wildlife Refuge...[survey] ..., March 11-23, 1965. 22 pp.

-----[1966]. Hawaiian Islands National Wildlife Refuge trip report. March 17-April 16, 1966. 24 pp.

-----[1966]. Hawaiian Islands National Wildlife Refuge trip --September 8-28, 1966. 34 pp.

-----[1967]. Refuge log book for 6 March - 1 April 1967. 39 pp.

-----[1967]. [Partial report of] Hawaiian Islands National Wildlife Refuge...[survey]..., September 10 through October 4, 1967. 14 pp.

-----[1968]. Field notes kept during the March 1968 survey of the Hawaiian Islands National Wildlife Refuge.

-----[1968]. Field notes kept during the August 1968 survey of the Hawaiian Islands National Wildlife Refuge.

-----[1969]. Hawaiian Islands National Wildlife Refuge spring trip. March 19-April 6, 1969. 32 pp.

Olsen, D.L. [1969]. Hawaiian Islands National Wildlife Refuge field trip, May 28-June 11, 1969. 18 pp.

Kridler, E. [1970]. Hawaiian Islands National Wildlife Refuge Field Trip Report. August 1970. 19 pp.

Olsen, D.C. [1971]. Expedition Report. Hawaiian Islands National Wildlife Refuge. Nihoa, Necker, French Frigate Shoals. August 16-27, 1971. 16 pp.

Kridler, E. [1971]. Hawaiian Islands National Wildlife Refuge Trip Report. September 2-17, 1971. 30 pp.

-----[1972]. Expedition Report. Hawaiian Islands National Wildlife Refuge. September 3-17, 1972. 28 pp.

Olsen, D.L. [1973]. Expedition Report. Hawaiian Islands National Wildlife Refuge. July 22-August 1, 1973 18 pp.

Christophersen, E., and E.L. Caum. 1931. Vascular plants of the leeward islands, Hawaii. B.P. Bishop Mus. Bull. 81: 1-41.

Clapp, R.B., and P.W. Woodward. 1968. New records of birds from the Hawaiian Leeward Islands. Proc. U.S. Nat. Mus. 124 (No. 3640): 1-39.

Clark, A.H. 1908. Descriptions of new species of crinoids, chiefly from the collections made by the U.S. Fisheries steamer "Albatross" at the Hawaiian Islands in 1902...Proc. U.S. Nat. Mus. 34 (No. 1608): 209-244.

-----1949. Ophiuroidea of the Hawaiian Islands. B.P. Bishop Mus. Bull. 195: 1-133.

Corney, P. 1896. Voyages in the northern Pacific....Honolulu, T.G. Thrum. x + 138 + v pp.

Dall, W., P. Bartsch, and H.H. Rehder. 1938. A manual of the recent and fossil pelecypod mollusks of the Hawaiian Islands. B.P. Bishop Mus. Bull. 153: 1-233.

Diggs, J.T. (ms.). Report of the cruise of the U.S.S. HERMES among the islands of the Hawaiian group, 1918. Rec. Group 45, U.S. Nat. Archives, Washington. 24 pp.

Edmondson, C.H., W.K. Fisher, H.L. Clark, A.L. Treadwell, and J.A. Cushman. 1925. Marine zoology of the tropical central Pacific. B.P. Bishop Mus. Bull. 27: ii + 148 pp.

Egler, F.E. 1938. Reduction of *Portulaca caumii* F. Brown to *P. villosa* Chamisso. Repent. Sp. Nov. Reg. Veget. 44: 264-265.

Elschner, C. 1915 The leeward islands of the Hawaiian Group. [Reprint from Honolulu Advertiser] Honolulu. 69 pp.

Ely, C.A., and R.B. Clapp. 1973. The natural history of Laysan Island, northwestern Hawaiian Islands. Atoll Res. Bull. 171: xi + 361 pp.

Emory, K.P. 1928. Archaeology of Nihoa and Necker Islands. B.P. Bishop Mus. Bull. 53: 1-124.

Fisher, W.K. 1903. Birds of Laysan and the leeward islands, Hawaii Group. U.S. Fish Comm. Bull. 23 (pt. 3): 767-807.

-----1906. The Starfishes of the Hawaiian Islands. U.S. Fish Comm. Bull. 23 (pt. 3): 987-1131.

-----1907. The holothurians of the Hawaiian Islands. Proc. U.S. Nat. Mus. 32 (No. 1655): 637-744.

Fowler, H.W. and S.C. Ball. 1925. Fishes of Hawaii, Johnston Island, and Wake Island. B.P. Bishop Mus. Bull. 26: 1-31.

Gilbert, C.H. 1905. The deep sea fishes. Bull. U.S. Fish Comm. 23 (pt. 2); iii-xi + 575-713.

Gregory, H.E. 1924. Report of the Director for 1923. B.P. Bishop Mus. Bull. 10: 1-38.

-----1925. Report of the Director for 1924. B.P. Bishop Mus. Bull. 21: 1-55.

Hamlet, O.C. (ms.). Letter to the U.S. Secretary of the Treasury dated 23 June, 1904...[giving details of apprehension of feather-harvesters]...Rec. Group 26, U.S. Nat. Archives, Washington. 9 pp.

Hardwick, D.F. 1965. The corn earworm complex. Mem. Ent. Soc. Canada 40: 1-247.

Hardy, D.E. 1964. Insects of Hawaii. Vol. 11. Diptera: Brachycera II - Cylorrhapha 1. E.C. Zimmerman, Ed. Univ. of Hawaii Press, Honolulu. vii + 458 pp.

Harry, R.R. 1953. Skin diving on a Polynesian expedition. Skin Diver 2: 6-7.

Hartman, O. 1966. Polychaetous annelids of the Hawaiian Islands. B.P. Bishop Mus. Occ. Papers 23: 163-252.

Harvey, T. 1860. Notes of a voyage to the Pacific in HMS "Havana". Naut. Mag. 29: 302-307, 358-361, 420-425, 521-525, 587-591.

Herald, E.S. 1952. "Pioneer" in the Pacific. Pac. Discovery 5 (5): 15-17.

Hillebrand, W.F. 1888. Flora of the Hawaiian Islands...Heidelberg: Carl Winter. xcvi + 673 pp.

Honolulu Advertiser. 1955. Much evidence of the past on Nihoa, p. A-1; col. 6-8, August 28, 1955.

Honolulu Star-Bulletin. 1935. Northrup Castle to talk on recent trip to westward islets, p. 4, col. 4, February 6, 1935; tells of voyage, p. 9, col. 7, February 9, 1935.

Jacobs, W.V.E. (ms.). Report to the Secretary of the Treasury of investigations and apprehension of Japanese plumage hunters in January 1910. Rec. Group 26, U.S. Nat. Archives, Washington. 18 pp.

Jacot, A.P. 1929. Concerning the genus *Neoliodes* (Oribatoidea-Acarina). Trans. Amer. Micro. Soc. 48: 30-43.

Jehl, J.R., Jr. 1968. Relationships in the Charadrii (shorebirds); a taxonomic study based on color patterns of the downy young. San Diego Soc. of Nat. Hist., Mem. 3: 1-54.

Kenyon, K.W., and D.W. Rice. 1959. Life history of the Hawaiian monk seal. Pac. Sci. 13: 215-252.

King, W.B. 1967. Seabirds of the Tropical Pacific Ocean. Preliminary Smithsonian Identification Manual. Smithsonian Institution, Washington, D.C. xxxiii + 126 pp.

Kramer, R.J. (ms.). Report on trip to Nihoa Island. December 1961. Hawaii Dept. of Fish and Game, Honolulu. 20 pp.

Kramer, R.J., and J.W. Beardsley. (ms.). A report on a survey trip to the Hawaiian Islands National Wildlife Refuge, June 1962. Hawaii Dept. of Fish and Game, Honolulu. iii + 17 pp.

Kroenke, L.W., and G.P. Woollard. 1965. Gravity investigations on the Leeward Islands of the Hawaiian Ridge and Johnston Island. Pac. Sci. 19: 361-366.

Labreque, A. 1957. A trip to Laysan Island. Elepaio 18: 16-19.

Lamoureux, C.H. 1964. The Leeward Hawaiian Islands. Haw. Bot. Soc. Newsletter. 3 (2): 7-11.

Lopes, H. de Souza. 1938. On the genus *Goniophyto* Townsend, 1927, with description of a new species from Hawaii. B.P. Bishop Mus. Occ. Papers 14: 193-197.

Maa, T.C. 1962. Notes on the Hippoboscidae (Diptera), I. Pac. Insects 4: 583-614.

-----1968. Records of Hippoboscidae (Diptera) from the central Pacific. J. Med. Ent. 5: 325-328.

Magnusson, A.H. 1942. Lichens of Nihoa and Necker Islands. B.P. Bishop Mus. Occ. Papers 17: 1-41.

Marshall, D.B. 1964. Treasure islands--of wildlife. Aud. Mag. 66: 160-165.

Meares, J. 1790. Voyage made in the years 1788 and 1789 from China to Northwest coast of America....London, Logographic Press (19) and xcv and 372 and (104) pp.

Morrell, B., Jr. 1841. A narrative of four voyages to the South Sea, North and South Pacific...from the year 1822 to 1831...Harper & Brothers, New York. 492 pp.

Moynihan, M. 1957. Notes on the sea birds of Sand Island of the Johnston Island group. Elepaio 18: 35-37.

Munro, G.C. 1941a. Birds of Hawaii...An Ocean Cruise. Elepaio 2: 34-36, 41-43, 49-51.

-----1941b. Birds of Hawaii...The Christmas Island Shearwater. Elepaio 2: 16-18.

-----1960. Birds of Hawaii. 2nd ed. Charles E. Tuttle Co., Rutland, Vermont. 192 pp.

Munter, W.H. 1915. Report of destruction of bird life on Laysan Island. Ann. Rep. Coast Guard for 1915: 130-140.

-----(ms.). Report to the Captain of the THETIS of bird observations made during a cruise to the Hawaiian Bird Reservation in January and February 1916. Rec. Group 26, U.S. Nat. Archives, Washington. 19 pp.

Nutting, C.C. 1905. Hydroids of the Hawaiian Islands collected by the steamer Albatross in 1903. U.S. Fish Comm. Bull. 23 (pt. 3): 931-959.

-----1908. Descriptions of the Alcyonaria collected by the U.S. Bureau of Fisheries Steamer Albatross in the vicinity of the Hawaiian Islands in 1902. Proc. U.S. Nat. Mus. 34 (No. 1624): 543-601.

Office of Geography. U.S. Department of the Interior. 1956. NIS [National Intelligence Survey] Gazetteer, Hawaiian Islands. Central Intelligence Agency, Washington, D.C. iii + 89 pp.

Ortman, A.E. 1905. Schizopods of the Hawaiian Islands collected by the ALBATROSS in 1902. U.S. Fish Comm. Bull. 23 (pt. 3); 961-974.

POBSP [Pacific Ocean Biological Survey Program], Smithsonian Institution [unpublished reports]:

Sibley, F.C. [1963]...[Report on]...Pacific Project field trip - June 1963. 18 pp.

Amerson, A.B., Jr. [1964]. Northwest Hawaiian Islands trip report, March 1964. 20 pp.

Fleet, R.R. [1964]. Leeward Islands Survey No. 5, September, 1964. 10 pp.

Banko, W. [1965]. Trip report...Hawaiian leeward islands survey...March 11-23, 1965. 11 pp.

Heiden, R.S. [1966]. Leeward Survey #14, Nihoa Island, 28 July - 1 August 1966. 9 pp.

Hackman, C.D. [1967]. Preliminary report of Leeward Island survey No. 18, March 6 to March 27, 1967. 12 pp.

Clapp, R.B. [1968]. LS #22, Preliminary Report, Nihoa Island. 9 pp.

Palmer, H.S. 1927. Geology of Kaula, Nihoa, Necker and Gardner Islands and French Frigate Shoals. B.P. Bishop Mus. Bull. 35: 1-35.

Paty, J. 1857. Account of the Manuokawai - Interesting account of her explorations. The Polynesian, 6 June: 40.

Paulding, H. 1831. Journal of a cruise of the United States Schooner Dolphin...G and C and H Carvill, New York. iv + 258 pp.

Peters, J.L. 1931. Check-list of birds of the world. Vol. I. Harvard Univ. Press, Cambridge, Mass. xvii + 345 pp.

-----1934. Check-list of birds of the world. Vol. II. Harvard Univ. Press, Cambridge, Mass. 401 pp.

Pilsbry, H.A. 1927. Littoral barnacles of the Hawaiian islands and Japan. Proc. Acad. Nat. Sci., Phila. 79: 308-317.

Powers, S. 1920. Notes on Hawaiian petrology. Am. J. Sci. 4th Ser. 50: 256-280.

Rathbun, M.J. 1906. The Brachyura and Macrura of the Hawaiian Islands. U.S. Fish Comm. Bull. 23 (pt. 3): 827-930.

Rice, D.W. 1960. Population dynamics of the Hawaiian monk seal. J. Mammal. 41: 376-385.

Rice, D.W., and K.W. Kenyon. 1962. Breeding distribution, history and populations of north Pacific albatrosses. Auk 79: 365-386.

Richardson, F. 1954. Report on the two native passerines of Nihoa, Hawaii. Condor 56: 30.

-----1957. The breeding cycles of Hawaiian seabirds. B.P. Bishop Mus. Bull. 218: 1-41.

Roach, F.L. (ms.). East Pacific Survey Phase I, U.S.S. Duval County, LST 758. (Typescript copy of report in the files of the 14th Naval District, Honolulu).

Ross, E.S. 1951. A new species of Embioptera from Oceania. Proc. Haw. Ent. Soc. 14: 307-310.

Rothschild, W. 1893-1900. The avifauna of Laysan and the neighboring islands. R.H. Porter, London. 3 parts. xx + xiv + 320 pp.

Sheehan, E. 1966. Scientific journey to mystery isle. Honolulu Advertiser, June 8, 1966.

Sibley, F.C., and R.W. McFarlane. 1968. Gulls in the central Pacific. Pac. Sci. 22: 314-321.

Snyder, J.O. 1904. A catalogue of the shore fishes collected by the steamer Albatross about the Hawaiian Islands in 1902. U.S. Fish Comm. Bull. 22: 513-538.

Strasberg, D.W. 1956. Notes on the blennioid fishes of Hawaii with descriptions of two new species. Pac. Sci. 10: 241-267.

St. John, H. 1970. The genus *Sicyos* (Cucurbitaceae) on the Hawaiian Leeward Islands. Hawaiian Plant Studies 35. Pac. Sci. 24: 439-456.

Stone, B.C. 1963. The genus *Portulaca* in the Hawaiian Islands. Advancing frontiers of Plant Science (New Delhi) 4: 141-149.

Thrum, T.C., comp. 1893. Hawaiian Almanac and Annual for 1894. T.G. Thrum, Honolulu. 162 pp.

-----1905. Hawaiian Almanac and Annual for 1906. T.G. Thrum, Honolulu. 255 pp.

Timberlake, P.H. 1924. Records of the introduced and immigrant chalcidflies of the Hawaiian Islands (Hymenoptera). Proc. Haw. Ent. Soc. 5: 418-449.

Tomich, P.Q. 1969. Mammals in Hawaii. A synopsis and notational bibliography. B.P. Bishop Mus. Spec. Publ. 47: 1-238.

Trempe, A.D. (ms.). Report on the bird life observed on the cruise of the Reliance in March 1936. Rec. Group 26, U.S. Nat. Archives, Washington. 5 pp.

Tsuda, R.T. 1966. Marine benthic algae from the leeward Hawaiian group. Atoll Res. Bull. 115: 1-13.

Usinger, R.L. 1942. The genus *Nysius* and its allies in the Hawaiian Islands. B.P. Bishop Mus. Bull. 173: 1-167.

Vanderbilt, G., and R.M. de Schauensee, 1941. Zoological results of the Vanderbilt Nihoa Expedition. I. Summary of zoological explorations and the birds of Nihoa. Notulae Naturae, Acad. Nat. Sci., Phila., No. 86: 1-14.

Vaughan, T.W. 1907. Recent Madreporia of the Hawaiian Islands and Laysan. U.S. Nat. Mus. Bull. 59: ix + 222 p.

Washington, H.S. and M.G. Keyes. 1926. Petrology of the Hawaiian Islands: V. The Leeward Islands. Amer. Jour. Sci., 5th ser., 12: 336-352.

Wetmore, A. (ms.). Field notes taken on the 1923 Tanager Expedition. (Original in possession of A. Wetmore).

-----1924. A warbler from Nihoa. Condor 26: 177-178.

-----1925. Bird life among lava rock and coral sand. Nat. Geog. Mag. 48: 77-108.

Wheeler, W.M. 1934. Revised list of Hawaiian ants. B.P. Bishop Mus. Occ. Papers 19 (21): 1-21.

Willett, G. (ms.). [Extracts from a report made to the Bureau of Biological Survey]. Bureau of Sport Fisheries and Wildlife, Kailua, Hawaii.

Woodside, D.H., and R.J. Kramer. (ms.). A report on a survey trip to the Hawaiian Islands National Wildlife Refuge, March 1961. Hawaii Dept. of Fish and Game, Honolulu. 32 pp.

Woodward, P.W. 1972. The natural history of Kure Atoll, northwestern Hawaiian Islands. Atoll Res. Bull. 164: xii + 318 pp.

Yashimoto, C.M. 1965. Synopsis of Hawaiian Eulophidae including Aphelininae (Hym: Chalcoidea), Pac. Insects. 7: 665-699.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 2. Apterygota to Thysanoptera. Univ. of Hawaii Press, Honolulu. viii + 475 pp.

-----1948b. Insects of Hawaii, Vol. 3. Heteroptera. Univ. of Hawaii Press. v + 255 pp.

-----1958a. Insects of Hawaii, Vol. 7. Macrolepidoptera. Univ. of Hawaii Press, Honolulu. ix + 542 pp.

-----1958b. Insects of Hawaii, Vol. 8. Lepidoptera: Pryaloidea. Univ. of Hawaii Press, Honolulu. ix + 456 pp.

Appendix Table 1. Scientific visits to Nihoa Island, 1885-1973

Date	Personnel	Vessel
1858?	Dr. Rooke	?
1885* 22 July	Princess Liliukolani	IWALANI
	E.M. Beckley	
	Sereno E. Bishop	
	W.E.H. Deverill	
	Sanford B. Dole	
	Mr. Hall	
	Mr. Jaeger	
	Mr. Williams	
	Some 200 others	
1891* 26-27 May	<u>Rothschild Expedition</u>	KAALOKAI
	Henry C. Palmer	
	George C. Munro	
1902* 1-3 June 5-9 Aug.	<u>Albatross Expedition</u>	ALBATROSS
	Charles H. Gilbert (SU)***	
	Walker K. Fisher (SU)	
	Charles C. Nutting (SUI)	
	John O. Snyder (SU)	
1912* 17 Dec.	George Willett (BBS)	THETIS
1914 7 Sept.	Capt. James H. Brown (USCG)	THETIS
	Carl Elschner	
1915 18 Mar.	Capt. James H. Brown (USCG)	THETIS
	Lt. William H. Munter (USCG)	
	4 members of crew	
1916 12 Feb.	Lt. William H. Munter (USCG)	THETIS
	Crew of THETIS	
1923 24-25 May	<u>Tanager Expedition</u>	TANAGER
	David L. Thaanum (BPBM) (conchologist)	
	Theodore T. Dranga (conchologist)	
	Chapman Grant (naturalist)	
11-20 June	<u>Tanager Expedition</u>	TANAGER
	Alexander Wetmore (BBS) (ornithologist)	
	William G. Anderson (collector)	
	A.L.C. Atkinson (HBAF)	

Appendix Table 1. (Continued)

Date	Personnel	Vessel
	Edwin H. Bryan, Jr. (BPBM) (entomologist) Bruce Cartwright (BPBM) (assistant in hydrographic work) Chapman Grant (BBS) (naturalist) Charles J. Judd (forester) Edward L. Caum (BPBM) (botanist) Harold S. Palmer (BPBM) (geologist) Eric L. Schlemmer (assistant to Wetmore) David L. Thaanum (BPBM) (conchologist) George Higgs (cook) C. Montague Cooke, Jr. (BPBM) (malacologist)	
1924 9-13 July	Tanager Expedition Harold S. Palmer (BPBM) (geologist) William G. Anderson (collector) William Bush (collector) Erling Christophersen (BPBM) (botanist) Theodore T. Dranga (BPBM) (conchologist) Kenneth P. Emory (BPBM) (archaeologist) Kenneth I. Hobson (collector) A. Landgraf (topographer)	TANAGER
1936 3 Mar.	A.D. Trempe B.L. Bassham (USCG) Other members of crew	RELIANCE
1940 7-16 Aug.	Mr. and Mrs. George Vanderbilt Clifton Weaver	NAVIGATOR
1951 July	George Vanderbilt Pacific Equatorial Expedition George Vanderbilt Vernon E. Brock (HDFG) B. Green Robert R. Harry (SU) Anita Vanderbilt Lucille Vanderbilt T. Ivar Vatland	PIONEER
1953 21-22 Dec.	Frank Richardson (UW)	BUTTONWOOD
1954 18 Mar.	Frank Richardson (UW)	BUTTONWOOD
1955 21-24 Aug.	Ivan T. Rainwater (USDA) George Carter David G. Nottage Peter Nottage Ed Sheehan	AUKAKA

Appendix Table 1. (Continued)

Date		Personnel	Vessel
1957	28 Dec.	Karl W. Kenyon (BSFW) Dale W. Rice (BSFW)	Aerial Survey
1961*	2 Mar.	David H. Woodside (HDFG) Raymond J. Kramer (HDFG)	PLANETREE
	10-15 Dec. (1600-0830)**	Raymond J. Kramer (HDFG) Gerald Swedberg (HDFG) HIRAN II personnel	FLOYD COUNTY
1962	10 June (0615-1345)	David B. Marshall (BSFW) John W. Beardsley (HSPA) Raymond J. Kramer (HDFG) David H. Woodside (HDFG)	STONE COUNTY Helicopter
1963*	5-6 June	A. Binion Amerson, Jr. (POBSP) Fred C. Sibley (POBSP)	TAWAKONI
1964	6-7 Mar. (1000-0800)	Eugene Kridler (BSFW) A. Binion Amerson, Jr. (POBSP) Loren Kroenke (UH) Edward O'Neill (BSFW) Ronald L. Walker (HDFG) George S. Wislocki (POBSP)	PLANETREE
	25 July (*ca.* 1000-1500)	Eugene Kridler (BSFW)	CHARLES H. GILBERT
	23-24 Sept. (0930-1700)	Eugene Kridler (BSFW) John Beardsley (UH) Robert R. Fleet (POBSP) Charles R. Long (POBSP) Ronald L. Walker (HDFG)	BASSWOOD
1965	13-14 Mar. (1045-1545)	Eugene Kridler (BSFW) Winston Banko (POBSP) Chandler S. Robbins (BSFW) Ronald L. Walker (HDFG)	BLACKHAW
1966*	18-20 Mar.	Eugene Kridler (BSFW) Andrew Berger (UH) Nelson Rice (HDFG) Ronald Walker (HDFG)	BUTTONWOOD
	28 July- 1 Aug.	Eugene Kridler (BSFW) Andrew J. Berger (UH) Richard S. Heiden (POBSP) Ernest Kosaka (HDFG)	CHARLES H. GILBERT

Appendix Table 1. (Continued)

Date		Personnel	Vessel
1967	8-9 Mar. (0945-1040)	Eugene Kridler (BSFW) C. Douglas Hackman (POBSP) Ernest Kosaka (HDFG) John Maciolek (BSFW) Richard Wass (UH)	BASSWOOD
	13-14 Sept. (0855-1420)	Eugene Kridler (BSFW) Robert Ballou (BSFW) John L. Sincock (BSFW) Ronald L. Walker (HDFG)	BUTTONWOOD
1968	7-9 Mar. (1130-1030)	Eugene Kridler (BSFW) Roger B. Clapp (POBSP) Karl W. Kenyon (BSFW) Ernest Kosaka (HDFG) John L. Sincock (BSFW)	IRONWOOD
	24-27 Aug. (0900-1400)	Eugene Kridler (BSFW) G. Brent Dalyrymple (USCG) Richard R. Doell (UDCG) C. Robert Eddinger (UH) Derral Herbst (UH) John L. Sincock (BSFW)	BUTTONWOOD
1969	21 Mar. (0900-1730)	Eugene Kridler (BSFW) Karl W. Kenyon (BSFW) George Laycock (NAS) David L. Olsen (BSFW) John L. Sincock (BSFW)	BUTTONWOOD
	29 May-10 June	David L. Olsen (BSFW) Ernest Kosaka (HDFG) James McVay (UH) William Patzert (UH) John L. Sincock (BSFW) Douglas Yen (BPBM)	MAHI
1970	15 Aug. (0830-1600)	Eugene Kridler (BSFW) Joseph Mazzoni (BSFW) David L. Olsen (BSFW) John L. Sincock (BSFW) David H. Woodside (HDFG)	BUTTONWOOD
1971	18-19 Aug. (0800-1230)	David L. Olsen (BSFW) David Childs (SI) Richard Grigg (HIMB) Robert J. Shallenberger (OI) James Vansant (UH) William Worcester (UH)	TERITU

Appendix Table 1. (Continued)

Date		Personnel	Vessel
	15 Sept. (1300-1800)	Eugene Kridler (BSFW) Erwin A. Bauer Kenneth S. Norris (OI) John L. Sincock (BSFW) Eric L. Schlemmer	BUTTONWOOD
1972	16 Sept. (0700-1500)	Eugene Kridler (BSFW) Russel Apple (USNPS) Bruce Benson (HA) Ernest Kosaka (HDFG) David L. Olsen (BSFW) John L. Sincock (BSFW)	BUTTONWOOD
1973	31 July (1030-1830)	David L. Olsen (BSFW) John L. Sincock (BSFW) Leighton Taylor (BSFW) Thomas Telfer (HDFG)	BUTTONWOOD

---

* No landing made on island.

** Time of arrival and departure, where known, is listed under the date of visit for surveys made during the 1960's.

*** Glossary of Abbreviations: BBS, Bureau of Biological Survey; BPBM, Bernice P. Bishop Museum; BSFW, Bureau of Sport Fisheries and Wildlife; HA, Honolulu Advertiser; HBAF, Hawaiian Board of Agriculture and Forestry; HDFG, Hawaii Division of Fish and Game; HIMB, Hawaii Institute of Marine Biology; HSPA, Hawaiian Sugar Planters Association; NAS, National Audubon Society; OI, Oceanic Institute, Waimanalo, Hawaii; POBSP, Pacific Ocean Biological Survey Program; SI, Smithsonian Institution; SU, Stanford University; SUI, State University of Iowa; UH, University of Hawaii; USDA, United States Department of Agriculture; USCG, United States Coast Guard; USCGS, United States Coast and Geodetic Survey; USNPS, United States National Park Service; UW, University of Washington.

Appendix Table 2. Results of scientific visits to Nihoa Island, 1885-1973

Date	Results
1858 ?	According to Hillebrand (1888: 451), seeds of the endemic palm were brought to Honolulu by a Dr. Rooke. We know nothing further of this visit.
1885 22 July	Topographic and geologic observations. Observations and collections of birds, none of which was subsequently reported. Archaeological material collected included a stone bowl and dish, a coral rubbing stone, and a coral file.
1891 26-27 May	Birds observed from offshore. 3 Red-footed Boobies collected and other birds observed (Munro, 1941a: 1941b).
1902 1-3 June	Observations of birds from offshore (Fisher, 1903).
5-10 Aug.	Collected offshore: corals, molluscs, hydroid, schizopod, crabs, fish, echinoderms, and bird specimens (at least 6 birds skins representing 3 species).
1912 17 Dec.	Observations of birds from offshore.
1914 7 Sept.	Island and its geology described; seeds and portions of *Pritchardia* taken to Honolulu. Plants collected.
1915 18 Mar.	Observations of birds and estimates of the numbers present; first published mention of the Nihoa Finch, palm seeds collected (Munter, 1915).
1916 12 Feb.	Observations of birds; photographs of flora and fauna; collected: plants; 5 specimens of the Nihoa Finch, reported and later described by W.A. Bryan (1916, 1917).
1923 24-25 May 11-16 June	Observations of birds and description of the Nihoa Millerbird (Wetmore, 1924, 1925). A new bird distributional record from the June 1923 visit was later reported by Clapp and Woodward (1968). 109 bird specimens (skins) of 17 species collected. Collections of: crustacea, echinoderms, foraminifera; fish, mollusca; marine algae, insects, vascular plants, rocks. Geology, topography, and archaeology described.

231-338 O - 77 - 17

Appendix Table 2. (Continued)

Date		Results
1936	3 Mar.	Observations of birds and their breeding status.
1940	7-10 Aug.	Observations and annotated bird list (Vanderbilt and de Schauensee, 1941); photographs taken and color movie of birds made. 48 birds of 12 species collected.
1951	July	Fish collected; 12 Nihoa Finches captured for transport to Honolulu Zoo of which 6 evidently reached the zoo (Herald, 1952: 15).
1953	21-22 Dec.	Observations of seabirds and their breeding status (Richardson, 1957); seal census taken but none found.
1954	18 Mar.	Observations of seabirds and their breeding status (Richardson, 1957); seal census taken but none found. Notes on status of Nihoa Finch and Millerbird (Richardson, 1954).
1955	21-24 Aug.	Charcoal collected for radioactive carbon dating; 3 or 4 Great Frigatebirds captured for transport to Honolulu Zoo; plants collected; an unfinished adz and a stone bowl collected; movies, photographs and tape recordings made.
1957	28 Dec.	Seal census taken but none found; aerial census of albatrosses (Rice and Kenyon, 1962).
1961	2 Mar.	Bird observations from offshore.
	10-15 Dec.	Observations of birds with particular emphasis on Nihoa Finches and Millerbirds; survey of vegetation with particular emphasis on status of Nihoa Palm; vegetation photostations established; effect of military activities investigated; plants collected; seeds of *Pritchardia* and *Chenopodium* collected for artificial propagation.
1962	10 June	Observations of birds with particular emphasis on the Nihoa Millerbird; brief notes on vegetation; collection of 15 species of insects and plant associates; effect of military activities investigated; photographs taken.
1963	5-6 June	Birds observed offshore; 2 Bulwer's Petrels collected.

Appendix Table 2. (Continued)

Date		Results
1964	6-7 Mar.	Observations of birds; seals and turtles censused; refuge signs erected; vegetation photographed. Collected: plants; limpets, and algae by Walker; 2 petrel chicks; arachnids. 99 birds of 11 species banded.
	25 July	Observations of birds and their breeding status.
	23-24 Sept.	Observations of birds with particular emphasis on the millerbird; census of turtles and seals; 57 birds of 5 species banded. Collected: plants, isopods, arachnids, insects, 1 lizard.
1965	13-14 Mar.	Observations of birds; turtles and seals censused; 312 birds of 9 species banded. Collected: 1 Sooty Storm Petrel, 1 lizard.
1966	28 July-1 Aug.	Observations of birds with particular emphasis on surveys of Nihoa Finch and Millerbird; turtles and seals censused; photographs taken of terrain; refuge sign erected. Collected: bird specimens; limpets by Berger. 1,544 birds of 8 species banded.
1967	8-9 Mar.	Observations of birds; turtles and seals censused; 45 Nihoa Finches captured by BSFW for introduction to French Frigate Shoals; 1 Millerbird and 46 Nihoa Finches banded. Collected: marine inshore organisms, hippoboscid flies, 1 finch.
	13-14 Sept.	Observations of birds with particular emphasis on Nihoa Finches and Millerbirds; transect censuses made of finch and Millerbird populations; 1 gecko and 1 finch collected.
1968	7-9 Mar.	Observations of birds with particular emphasis on Nihoa Finches and Millerbirds; transect censuses made of finch and Millerbird populations; turtles censused; plants collected; 105 birds of 5 species banded.
	24-27 Aug.	Observations of birds with particular emphasis on Nihoa Finches and Millerbirds; transect censuses made of finch and Millerbird populations; turtles and seals censused; collection of rock samples for analysis of magnetic properties; observations of vegetation; ectoparasites collected from finches; 42 birds of 3 species banded.

Appendix Table 2. (Continued)

Date		Results
1969	21 Mar.	Observations of birds, censuses of turtles and seals; island vegetation cover mapped; partial censuses made of finch and Millerbird populations. 2 Sooty Storm Petrels banded.
	29 May-10 June	Observations of birds with particular emphasis on Nihoa Finches and Millerbirds; transect censuses of finch and Millerbird populations; ethnobotanical surveys, marine survey of surrounding waters, retrieval of current meters, vegetation photostation photographs obtained. 224 birds of 2 species banded.
1970	15 Aug.	Observations of birds, transect censuses of finch population.
1971	18-19 Aug.	Observations of birds; transect censuses made of finch and Millerbird populations. Offshore marine observations.
	14-15 Sept.	Cursory observations made of birds, seals and turtles. Several archaeological samples obtained for Carbon-14 dating.
1972	16 Sept.	Observations of birds, seals and turtles; transect censuses made of finch and Millerbird populations.
1973	31 July	Cursory observations of birds. Seals noted; transect censuses made of finch and Millerbird populations.

Appendix Table 3. Publications on collections and studies (with the exception of birds) made on Nihoa Island, 1885-1973*

Protozoa

Cushman in Edmondson *et al.*	Reports 15 species of foraminifera collected offshore by the Tanager Expedition.

Coelenterata

Nutting, 1905.	Reports 1 species of hydroid collected south of Nihoa by the Albatross Expedition.
Vaughan, 1907.	Reports 6 species of corals (Madreporia) collected offshore by the Albatross Expedition.
Nutting, 1908.	Reports 11 species of coral (Alcyonaria) collected by the Albatross Expedition; most are described as new species.

Mollusca

Pilsbry, 1927.	Lists a barnacle collected by the Tanager Expedition.
Dall, *et al.*, 1938.	Lists two species of pelecypods collected offshore by the Albatross Expedition.

Annelida

Hartman, 1966.	Summarizes published records of polychaetes (1 species); gives current taxonomy.

Arthropoda

Arachnomorpha (Arachnida)

Bryan, *et al.*, 1926.	States that bird ticks were found abundantly.
Jacot, 1929.	Reports an orabatid mite (Acarina) from collections made by the Tanager Expedition.
Beardsley, 1966.	Reports 5 Araneida and an undetermined pseudoscorpion from collections made in September 1964. First record of the occurrence of pseudoscorpions.
Amerson, 1968.	Reports the distribution and hosts of ticks from collections made by the POBSP.

Appendix Table 3. (Continued)

Crustacea

Ortman, 1905.	Reports a single species of schizopod collected in the vicinity of Nihoa by the Albatross Expedition.
Rathbun, 1906.	Reports brachyuran and macruran crabs collected offshore by the Albatross Expedition.
Edmondson *in* Edmondson *et al.*, 1925.	Reports 3 species of decapods collected by the Tanager Expedition.
Bryan *et al.*, 1926.	Indicates that isopods were collected by the Tanager Expedition.
Beardsley, 1966.	Lists 2 species of isopods from collections made in September 1964.

Labiata (Hexapoda - Insects)

Timberlake, 1924.	Records a chalcid fly collected by the Tanager Expedition.
Bryan *et al.*, 1926.	Reports *ca.* 67 species of insects collected by the Tanager Expedition.
Wheeler, 1934.	Lists 4 species of ants on the basis of earlier publications.
Lopes, 1938.	Describes a new species of sarcophagid fly from collections of the Tanager Expedition.
Usinger, 1942.	Reports 3 species of *Nysius* (Hemiptera: Lygaeidae), 2 described as new, from collections by the Tanager Expedition.
Zimmerman, 1948a.	Lists 8 species of insects (1 thysanuran, 4 cockroaches; 1 embiopteran, and 1 earwig. Zimmerman's various distributional records in the Insects of Hawaii series derive from the Tanager collections, but extensively revise taxonomy, reidentify specimens, and identify to species hitherto unidentified specimens; several new distributional records are listed in the series.
Zimmerman, 1948b.	Lists 6 species of Hemiptera (4 lygaeids, 1 nabid, and 1 anthocorid).

Appendix Table 3. (Continued)

Ross, 1951.	States that the embiopterid collected by the Tanager Expedition and reported as *Oligotoma insularis* (Bryan *et al.*, 1926) is actually *Oligotoma (Aposthonia) oceania* Ross sp. nov.
Zimmerman, 1958a.	Lists 2 species of noctuid moths.
Zimmerman, 1958b.	Lists 1 pyralid moth and 1 pterophorid moth.
Maa, 1962.	Reports specimens of Hippoboscidae collected by the Tanager Expedition.
Hardy, 1964.	Identifies a dolicopodid fly not specifically identified in Bryan *et al.*, 1926.
Yashimoto, 1965.	Lists 2 species of eulophids (Hymenoptera: Chalcoidea).
Hardwick, 1965.	Describes a noctuid moth from specimens collected by the Tanager Expedition.
Beardsley, 1966.	Reports 110 species of insects collected in June 1962 and September 1964, 41 of them new distribution records. Lists earlier records of insects but does not include Mallophaga.
Maa, 1968.	Reports POBSP collections of hippoboscid flies.
<u>Echinodermata</u>	
Fisher, 1906.	Reports 9 species of starfishes (Asteroidea) from collections made by the Albatross Expedition offshore.
Fisher, 1907.	Records 3 sea cucumbers (Holothuroidea) collected by the Albatross Expedition.
Agassiz and Clark, 1907-1912.	Records 9 species of Echinoidea collected by the Albatross Expedition.
Clark, 1908.	Reports a crinod collected from offshore by the Albatross Expedition.
Clark *in* Edmondson *et al.*, 1925	Reports 3 species of Echinoidea collected by the Tanager Expedition

Appendix Table 3. (Continued)

Clark, 1949.	Reports 10 brittle stars (Ophiuroidea) collected by the Albatross Expedition. Summarizes previous records for echinoderms.
Chordata	
Vertebrata	
Pisces	
Snyder, 1904.	Reports 1 species collected by the Albatross Expedition.
Gilbert, 1905.	Records 22 species of deep sea fishes collected in the vicinity of Nihoa by the Albatross Expedition.
Fowler and Ball, 1925	Reports 7 species of fish collected by the Tanager Expedition.
Strasberg, 1956.	Revises taxonomy of Hawaiian blennioid fishes and records 1 species from Nihoa.
Reptilia	
Beardsley, 1966.	Gives first record of a lizard, *Lepidodactylus lugubris*, from a collection made in September 1964.
Mammalia	
Paty, 1857.	First report of seals at Nihoa.
Kenyon and Rice, 1959.	Reports no seals seen during visits by Richardson in 1953, and 1954.
Rice, 1960b.	Reports no seals seen on aerial survey December 1957.
Tomich, 1969.	Reports occurrence of monk seal in March 1965.
Flora	
Beccari, 1889.	Describes endemic palm (*Pritchardia remota*) from cultivated specimen from Honolulu.
Bryan, 1916.	Indicates palm seeds were collected during the April 1915 cruise of the THETIS. The

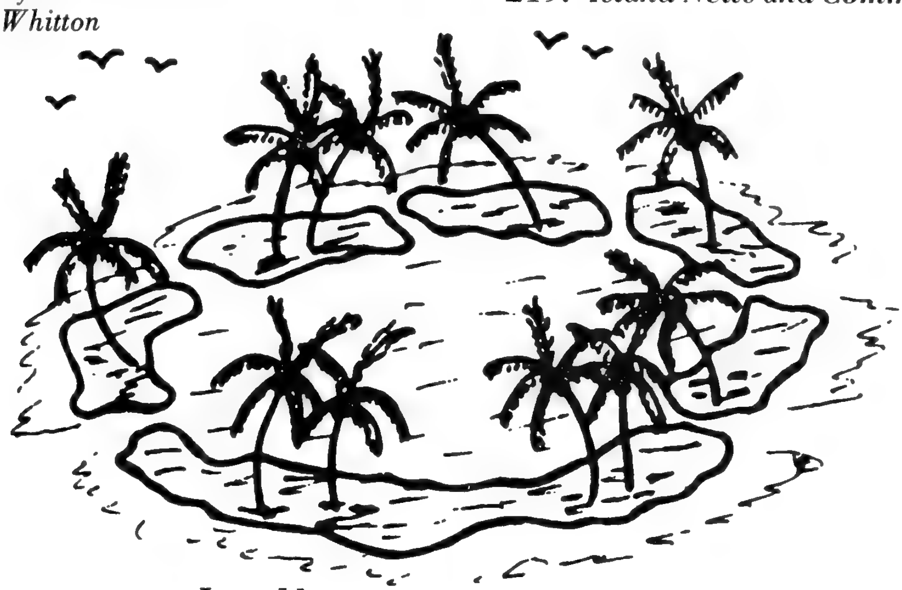
Appendix Table 3. (Continued)

	THETIS visited Nihoa in March not April 1915 and two reports of the visit give no indication that plants were collected then. In actuality the seeds were collected in September 1914 (see next entry).
Beccari and Rock, 1921.	Remarks on *Pritchardia* specimens collected in September 1914.
Christophersen and Caum, 1931	Reports 20 species of vascular plants collected by the Tanager Expedition.
Magnusson, 1942	Lists 19 species of lichens collected by the Tanager Expedition.
Lamoureux, 1964.	Reports that the 11 species of vascular plants collected by the HDFG in 1962 are represented in the 20 species collected by the Tanager Expedition in 1923.
Tsuda, 1966.	Reports 2 species of marine benthic algae from collections made in July 1924 and March 1964.
<u>Geophysical</u>	
Bishop, 1885a and b.	Gives geological and topographical observations made in 1885.
Elschner, 1915.	Gives descriptions and geological comments from observations made offshore in September 1914.
Powers, 1920.	Records observations on a rock specimen stated (erroneously) to have been collected by W.A. Bryan.
Washington and Keyes, 1926.	Reports results of studies of rocks collected in 1914 and 1923.
Palmer, 1927.	Gives geological and topographical observations made by the Tanager Expedition.
Kroenke and Woollard, 1965.	Reports gravity observations made in March 1964.
<u>Archaeology</u>	
Emory, 1928.	Reports on archaeological work conducted by the Tanager Expedition and summarizes all available information.

U. S. GOVERNMENT PRINTING OFFICE : 1977 O - 231-338

Nos. 208-219 May 1977

ATOLL RESEARCH BULLETIN



Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

ATOLL RESEARCH BULLETIN
NO. 208

NOTES ON PLANTS OF THE GENUS CAULERPA IN THE HERBARIUM OF MAXWELL S. DOTY AT THE UNIVERSITY OF HAWAII

by Wm. Randolph Taylor

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

NOTES ON PLANTS OF THE GENUS CAULERPA IN THE HERBARIUM OF MAXWELL S. DOTY AT THE UNIVERSITY OF HAWAII

by Wm. Randolph Taylor [1]

In 1966 on the invitation of Professor Maxwell S. Doty I spent several weeks at the University of Hawaii to review his holdings of certain algal genera, particularly those of *Caulerpa* (Chlorophyceae-Siphonales), and especially the Pacific specimens.[2,3] In view was the rectification of the determinations, where necessary, and the organization of the genus as represented in the collection from a single viewpoint. This I did at that time, but because of other work in hand was unable to consider preparing a report for publication.

More recently, pressed to make such a report, I sent for and received the more troublesome part of the material on loan, and have

---

[1] Department of Botany, University of Michigan.

[2] This study while in Honolulu was conducted under an Atomic Energy Commission Contract no. AT(04-3)-235 to Prof. Maxwell S. Doty, and later continued at the University of Michigan under Nat. Sci. Found. grant GB-3186 in part, for which help the writer is most thankful.

[3] The last names of the principal collectors of the materials reported in this paper are associated with the collection number in each case, but in order that their identity may be more accurately defined their initials where available are given in the following list:
Alcala, A.C.; Almazan, M.; Alvarez, V.; Buggeln, R.; Cooper, J.; Doty, M.S.; Engard, C.J.; Fong, E.; Gilmartin, M.; Hair, L.E.; Halstead, B.; Hastings, C.F.; Horwitz, L.; King, J.E.; Kraft, G.T.; Littler, M.M.; Long, C.R.; Matsui, T.; Meñez, E.G.; Newhouse, G.; Pages, P.; Randall, J.; Rogers, D.P.; Sachet, M.-H.; Santos, G.A.; Seiburth, J.; Soegiarto, A.; Sorokin, Y.; Stone, B.C.; Strasburg, D.W.; Trono Jr., G.C.; Tsuda, R.; Velasquez, G.T.; Villaroya, M.L.; Wainwright, S.A.; Wreede, R.E. de.

(Manuscript received January 1974--Eds.)

gone over it again. On the basis of my 1966 notes, review of material accessioned since then, and reconsideration of the specimens loaned in 1972 I present here a list of representative western and central Pacific *Caulerpa* material in that herbarium, excluding Japan, Australia and New Zealand. This is probably the largest representation of that genus from the area in any herbarium. Because of the very great duplication of specimens from certain localities I only cite a few examples from each, but attempt to include all significant places which could be located geographically.

When I agreed to go over the great bulk of material again and to prepare this report I was unaware that G.C. Trono had (1968) published on the Caroline Islands material, or was later to publish (Trono 1972a, b; 1973) on Philippine material, leading to great duplication of effort without commensurate yield of new data. However, since this present paper covers the central and western Pacific (south of Japan, north or east of Australia) in general, and since the citation again of Caroline Island and Philippine specimens could be kept to a minimum, it seems wise to include them where necessary to complete the tale of Honolulu holdings.

It does not seem needful to review here the literature on Pacific green algae, as this is not an historical paper. Nor is it a summation of all accounts of *Caulerpa* in the western Pacific. Necessarily the basis for any account of the genus is the monograph by Mme Anna A. Weber-van Bosse (1898). Mention of the genus occurs in many of the more general papers. A good deal of this literature has already been brought together, in Okamura (1916), Taylor (1950, 1966), May (1953, 1966a, b), and Dawson (1956, 1957), while Gilbert has also listed it (1959) and Abbott (1961), Trono (1968) and Womersley and Bailey (1970) have extended it still further.

Nor can too detailed conclusions be drawn respecting the geographical ranges of the species listed. For this all other major herbaria concerned with the area should be consulted. Nevertheless very many extensions of range are involved, and we do get some idea of what species are commonest throughout the central and western Pacific. It is clear that *Caulerpa lentillifera, C. mexicana, C. peltata, C. racemosa* in particular, *C. serrulata* and *C. urbilliana* are by far the commonest. The substantial representation of the very small *C. ambigua* about Hawaii probably reflects the closer observation possible from a well-equipped scientific center. Other small species seldom mentioned, like *C. elongata, C. webbiana* and smaller forms of *C. fastigiata* probably have been missed by reason of a lack of close search.

Some species are nearly ubiquitous in the subtropics and tropics around the world, and in this we could include, with others, *C. cupressoides, C. racemosa* and *C. sertularioides*. On the other hand *C. lentillifera* does not come into the Atlantic flora, though found from the Marshall Islands to the Red Sea, parallelling *C. urvilliana*

ranging from the Line Islands west to Mauritius, absent from the Atlantic. Disproportionate abundance is suggested in some cases, for *C. serrulata* seems to be far more abundant in Pacific collections than West Indian, though found in both oceans, while the reverse seems to be the case with *C. cupressoides*.

Less familiar species are harder to evaluate as to range. They may have a scattering, sparse distribution. First found in the Marshall Islands, *C. bikinensis* is now known to reach the Tuamotu group. From the Carolines to the Philippines is about the range of *C. lessonii*. We must not discount the possibility of migration to new areas after a long period of limitation to an old range. For instance, *C. scapelliformis*, long known from the Red Sea to south Australia and Japan has of recent years turned up in Brazil and Guadeloupe, and by 1966 abundantly in Barbados and Antigua, areas where such a relatively large and distinctive alga could hardly have grown unrecorded through the previous decades. If one is reluctant to deny its earlier presence there one must remember the case of *Codium fragile* (Sur.) Hariot, much more closely documented in its migration from the Pacific to the eastern coast of the United States, eventually reaching northern New England. There it was never seen until recent years, in an area of intensive observation of the marine algae, but it is now abundant enough to constitute a nuisance to the shellfish industry.

List of specimens

Caulerpa ambigua Okam.

HAWAII

LAYSAN I., from the s.w. side, Tsuda no. T-548, 6 xii 63.
KAUAI I., Anahola, Doty no. 10224, 7 ii 52.
OAHU I., Waikiki Beach, Choy, 16 iii 54, Doty no. 13063a, 4 xii 55, Ewa Beach, Littler no. 26500, 2 vi 70.

Caulerpa antoensis Yamada[1]

MARSHALL ISLANDS

ARNO ATOLL, Ine Village, Horwitz no. 9040, 10 vii 51.

CAROLINE ISLANDS

PINGELAP I., Meñez no. 21926, 1 vii 60.
MOKIL IDS., Urak I., Meñez no. 21344, 29 vi 60.
PULUWAT I., Meñez no. 23236, 7 viii 60.
IFALUK IDS., Ifaluk I., Meñez no. 23055, 10 viii 60; Ella I., Meñez no. 23232, 10 viii 60; between Ifaluk I. and Falalap I., Meñez no. 23102, 10 viii 60.

A fragment of Yamada's original material (Yamada 1941, 1944a, b) from Ant Atoll near Ponape Island in the eastern Carolines, which he kindly sent me after my Bikini book appeared, showed very short axes

---

[1] *C. arenicola* Taylor 1950.

and irregularly disposed ramelli, but his 1941 figure, far better than that of 1944a which accompanied his formal description, shows them bilaterally disposed in large part. The ramelli on his plant are a little thicker than on the Bikini plants, reaching at least 200 µm. On some of the Caroline Island specimens they were only 135 µm diam, but in others reached 264 µm.

Caulerpa bikinensis Taylor

TUAMOTU ARCHIPELAGO

RAROIA I., Tomokgolu (? Tomogagie), Doty & Newhouse no. 11426, 29 vii 52.

Caulerpa brachypus Harv.

LINE ISLANDS

PALMYRA I., Long no. 2833, 27 xi 64.

MARSHALL ISLANDS

MAJURO ATOLL, Seiburth & Sorokin, no number, ii 70.

CAROLINE ISLANDS

PULUWAT I., Meñez nos. 23064, 23091, 7 viii 60; these included strongly dentate specimens.

YAP I., Meñez no. 21489, 19 viii 60.

PHILIPPINE ISLANDS

SAMAR I., Samar Prov., Guiuan, Santos no. 20466, 29 iv 48 (not dentate), Guiuan, Hinatunglan, Santos no. 26462, 17 vi 69 (very attenuate).

NEGROS I., Negros Oriental Prov., Siquijor I., Carrio Solong-on, Alcala no. 20522, n.d., Meñez nos T-1132, T-1137, 28 ix 67, Santos nos. 26042, 26047, 22 v 69, 26197, 26221, 26 v 69.

PALAWAN I., Palawan Prov., Cujo I., Meñez 16537, 30 iv 58.

MINDANAO I., Surigao del Norte Prov., Surigao, Meñez no. 18363, n. d.; Zamboanga City Prov., Little Santa Cruz I., Santos 26544, 26 viii 71.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty & Hair no. 25418, vi 66; Siasi Group, Siasi I., Doty & Hair no. 25537; Tawitawi Group, Bilitan I., Doty & Hair no. 25499, 5 viii 66; Sibitu Group. Tumindao I., Sitangkai, Doty & Hair no. 25451, vii 66.

Caulerpa cupressoides (West) C. Ag.

LINE ISLANDS

FANNING I., Tenupa, Wainwright no. 20101, 2 vii 63

MARSHALL ISLANDS

ARNO ATOLL, Ine Village, Doty no. 9001, 26 v 51.

CAROLINE ISLANDS

KUSAIE I., Lele Harbor, Meñez no. 15852, 16 vii 60, Tafsanak Village, Meñez no. 23407, 16 vii 70; Utwa I., Meñez no. 23248, 17 vi 60.

PINGELAP I., Meñez nos. 21312, 21935, 7 viii 60.

TRUK IDS., Quoi I., Meñez no. 23191, 2 viii 60; Moen I., Meñez 15901, 31 vii 60; Fefan I., Meñez no. 23081, 8 viii 60; Falas I., Meñez no. 23513, 30 vii 60.

ULUL I., Meñez no. 15883, 6 viii 60.
PULUWAT I., Meñez nos. 23131, 23235, 7 viii 60.
IFALUK I., Meñez no. 23126, 10 viii 60; between Ifaluk I. and Falalap I., Meñez no. 23063, 10 viii 60.
SOROL I., Meñez nos. 23049, 23162, 13 viii 60.
YAP I., north of harbor channel, Meñez nos. 21572, 23092, 18 viii 60.
HELEN I., reef, Meñez no. 15415 *p.p.*, 28 viii 60.

PHILIPPINE ISLANDS
LUZON I., Quezon Prov., Baler, Diksalarin, Velasquez no. 16469B, 23 iv 66.
CATANDUANES I., Catanduances Prov., Benticayan s. of Vinticayan Point, Doty & Velasquez no. 16655, 21 v 58.
SAMAR I., Samar Prov., Guiuan, Pagnamiton, Doty & Alvarez no. 14324, 4 ii 65.
MINDANAO I., Zamboanga City Prov., Sacol I., Doty & Hair no. 25398, 22 vi 66.
SULU ARCHIPELAGO, Jolo Group, Pangasinan I., Doty 25421, vi 66; Tapul Group, Siasi I., Doty & Hair no. 25525, 10 viii 66; Tawitawi Group, Tawitawi I., Balimbing Pt., Meñez no. 1101, 23 ix 67; Bilitan I., Doty & Hair no. 25484, 5 viii 66.

Caulerpa elongata Weber-van Bosse

MARSHALL ISLANDS
ARNO ATOLL, Horwitz no. 9046, 10 vii 51.

CAROLINE ISLANDS
YAP I., Meñez no. 23780, 19 viii 60.

PHILIPPINE ISLANDS
LUZON I., Sorsogon Prov., Bulusan, Kraft no. 349, 17 Mar. 68.

Caulerpa fastigiata Mont.

CAROLINE ISLANDS
KUSAIE I., Tafansak, Meñez no. 21955, 16 vii 60; Utwa I., Meñez no. 23714, 17 vii 60.

PHILIPPINE ISLANDS
SAMAR I., Samar Prov., Guiuan, Pagnamiton, Doty & Alvarez no. 14332, 4 ii 65.
NEGROS I., Negros Oriental Prov., Siquijor I., Carrio Solong-on, Santos nos. 26052, 26160, 22 v 69.

Caulerpa fergusonii Murray

PHILIPPINES
LUZON I., Sorsogon Prov., Bulusan, Santos no. 26522, 9 viii 71.

Caulerpa lentillifera J. Agardh

CAROLINE ISLANDS
TRUK IDS., Fefean I., Meñez without number, 28 vii 60.

PHILIPPINE ISLANDS
LUZON I., Batangas Prov., Matabungkay, Santos no. 20450 *p.p.*, 3 iv 68. Pangasinan Prov., Hundred Islands, Virgin Cave I., Doty & Meñez 16342, 15 ii 58.

CATADUANES I., Cataduanes Prov., Virac Point, Doty & Velasquez no. 16746, 20 v 58.
SAMAR I., Samar Prov., Guiuan, Hinatunglan, Santos 26461, 17 vi 69.
CEBU I., Cebu Prov., Cebu City market, n. coll., no. 18318, 14 vii 58; Mactan I., Cordova, at *Caulerpa*-farm, Doty no. 16075, 17 i 58, Calawisan, Meñez no. T-1027, 8 ix 67.
NEGROS I., Negros Oriental, Siquijor I., Solong-on, Alcala nos. 20520, 20523, Santos nos. 26198, 26 v 69.
PALAWAN I., Palawan Prov., Pto. Princesa, Inagawan, Velasquez no. 3079, 20 vi 51; Cujo I., Cujo, Meñez 16535, 30 iv 58.
MINDANAO I., Davao Prov., Davao, Sasa Wharf, Doty no. 18056, 26 vi 68; Zamboanga Prov., Little Santa Cruz I., Menez no. T-1057, 10 ix 67; Sacol I., dwarf, Meñez no. T-1096, 19 ix 67.
SULU ARCHIPELAGO, Sulu Prov., Tapul Group, Siasi I., Doty & Hair no. 25530, 10 viii 66, Sibaud I., Santos nos. 26545, 26559, 14 ix 71; Manubal I., Doty & Hair no. 25529, 10 viii 6; Tapaan I., Doty & Hair no. 25574, Trono T4064, T4087, 29 xii 70. Tawitawi Group, Bilitan I., Doty & Hair nos. 25501, 25511, 5 viii 66; Tawitawi I., Balimbing Pt., Meñez no. T-1102, 23 ix 67.

The size of the ramelli on plants assignable to this species seems to vary greatly. In most specimens they are small, as we find in Cebu I. no. 18318, where the diameter is about 1.5 mm. In contrast, one places Bilitan I. no. 25511, where they are over 4 mm in the dry state. Similar coarse plants were found at Rongelap lagoon (Taylor 1950, p. 67) and it is possible that we are dealing with two species, rather than one very variable one.

Caulerpa lessonii Bory

CAROLINE ISLANDS
TRUK IDS., Fefan I., Meñez no. 23029, 28 vii 60.
YAP I., Yap Harbor, Meñez no. 23144, 18 viii 60.
PHILIPPINE ISLANDS
LUZON I., Pangasinan Prov., Lingayan Gulf, Cabarruyan I., Anda, Santos no. 20406a, 22 ii 68. La Union Prov., San Fernando, Almazan no. 1300, 3 iii 68.

This group of Caulerpas from the islands gave me much concern because of a marked similarity to *C. cupressoides* var. *lycopodium* f. *elegans* (Crouan) Weber-van Bosse of the West Indies. They also resemble the figures and descriptions of *C. lessonii* Bory and *C. distichophylla* Sond. However, Prof. H.B.S. Womersley informs me that the ramelli of *C. distichophylla* are compressed, not terete as described by Mme Weber-van Bosse (1898, p. 341), and as are those of our plants, and as the type locality for the species *lessonii* is in the Caroline Islands the probability is strong that plants like these were what Bory had in hand, though I have not actually had the type to examine. The relation of the v. *lycopodium* f. *elegans* to *C. cupressoides* seems to me rather insecure, and these *lessonii* plants would have even less claim to relationship.

Caulerpa macrodisca Decne.

PHILIPPINE ISLANDS

CEBU I., Mandaue (Mandawi), north of Cebu City, Quijano no. 429, 6 vii 64.

Caulerpa mexicana (Sond.) J. Agardh

HAWAIIAN ISLANDS

KAUAI I., Haena Point, Randall no num., dwarf, 11 xi 51.

OAHU I., Hanauma Bay, Doty no. 3936, 13 xi 51; Lanikai, Strasburg no num., 26 x 52; Maili, Rogers no num., 11 v 56; Waimanalo Beach, C.F. Hastings no. 282, 15 ix 68.

LANAI I., Huawai Bay, Degener no. 28691, 9 i 64; Kapihaa Bay, Doty & Lee no. 22071, 27 xi 60; Kaumalapau, Doty & Lee no. 22111 28 ix 60.

MAUI I., Lahaina, Matsui no. 12862, ix 55.

PHILIPPINE ISLANDS

LUZON I., Sorsogon Prov., Bulusan, Santos no. 26253, 4 vi 69; La Union Prov., San Fernando, Almazan no. 1306-2, 3 iii 65.

In western Atlantic waters *C. mexicana* and *C. taxifolia* are readily distinguished. Only in dwarfed plants about 1 cm tall are the characters so ill-developed as to lead to indecision. This is not so in the Pacific. Intermediates are not infrequent, and numbers 282, 12862, 22071, 22111, 26253 may be considered examples tending that way. It seems to me possible that the basic stock simply evolved two types clearly in one ocean but did not proceed so far in another. To blindly disregard that achieved potential shown in the Atlantic and reduce *C. mexicana* to synonymy seems to me quite the wrong attitude. Better to recognize that some plants have, in the Pacific, the full characters of *C. mexicana* and call them by that name, others of *C. taxifolia,* and that intermediates exist either by lack of complete evolutionary divergence or, as an alternative hypothesis, by hybridization.

To point out the characters of these two species in their distinct forms, I would suggest the following. For *C. taxifolia* I expect relatively narrow blades, usually long, with a narrow axis, and with ramelli of the order of 0.75-1.20 mm in width, about 5-12 times as long. There is little tapering toward the base, and tapering to the tip is gradual. They are strongly compressed, but are only about 3 times as broad as thick. Børgesen's illustrations (1913, figs. 104, 105) are good.

For *C. mexicana* I expect relatively broader blades, usually short, with broader axes and broader ramelli up to 1.0-2.5 mm wide, 2.5-5.0 times as long. They show substantial narrowing at the base, and at the tips they are more abruptly rounded-tapered as a rule. They are flat, and may be 10-30 times as broad as thick. They are often so close that they overlap distally, though in the var. *laxa* (Weber-van Bosse) Taylor they are widely spaced. Mme Weber-van Bosse's figure (1898) pl. XXIV no. 2 (as *C. pinnata* fa. *mexicana*),

although of a rather small individual, represents this species fairly well. Perhaps mine (1960, pl. 12, fig. 5) is a little better.

Caulerpa peltata Lamx.

HAWAIIAN ISLANDS

LAYSAN I., west side, Tsuda no. T-523, 6 xii 63.

NECKER I., Long no. T-943, 25 ix 64.

KAUAI I., Anahola Bay, Doty no. 10022, 2 ii 52.

OAHU I., Oli Bridge near Koko Head, Doty no. 8382; Kaneohe Bay, Moku-O-Loe (Coconut) Island, Littler no. 20538, 10 x 68.

LINE ISLANDS

FANNING I., Danger Point Pool, Wainwright no num., 9 vii 63.

MARSHALL ISLANDS

ARNO ATOLL, Ine Village, Horwitz no. 9080 with disks to 9 mm diam. dry, 26 v 51.

CAROLINE ISLANDS

PONAPE I., Epwelkapw, Meñez no. 15675, 20 vi 60.

TRUK IDS., Truk I., Meñez no. 21059, 31 vii 60; Moen I., Meñez no. 23693, 29 vii 60; between Moen and Falo Ids., Meñez no. 23383, 29 vii 60.

PALAU I., Iwayama Bay, Meñez no. 15102a, 22 viii 60.

PHILIPPINE ISLANDS

LUZON I., Quezon Prov., Baler, Digisit, Velasquez no. 16989, 24 iv 58; Sorsogon Prov., Bulusan, Santos no. 26513, 6 viii 71.

MINDORO I., Mindoro Oriental Prov., Puerto Galera, Sabang Cove, Velasquez no. 1632, 8 v 48.

NEGROS I., Negros Oriental Prov., Dumaguete City, Santos no. 26012, 20 v 69, Matio Beach, Santos no. 26080, 24 v 69, Uy-Pitching Beach, Santos no. 26149 (very good), 25 v 69, Mataio Beach, Santos no. 26024 (very good), Lo-Ok Beach, Santos no. 26244 (superb), 28 v 69.

MINDANAO I., Zamboanga Prov., Zamboanga City, Arena Blanco, Santos no. 26538, 24 viii 71.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty & Hair no. 25245, 1966.

Caulerpa pickeringii Harv. & Bail.

TUAMOTU ARCHIPELAGO

RAROIA ATOLL, outer reef, Doty & Newhouse no. 11162, 9 vii 52; Okarekare, Doty & Newhouse no. 11228, 1 viii 52.

Caulerpa racemosa (Forssk.) J. Agardh

HAWAIIAN ISLANDS

LAYSAN I., Tsuda no. T-541, T-594, 6 xii 63.

NECKER I., Long no. T-944, 25 ix 64.

KAUAI I., Anahola Bay, Doty nos. 9999, 10231, 2-7 ii 52.

OAHU I., Hanauma Bay, Doty no. 10672, 3 v 53, no. 10616, 5 iv 53; Manana (Rabbit) I., Doty no. 8833, 22 iv 51; Kaneohe Bay, Doty no. 8459, 24 xi 50; Ulupau Head, Kii Point, Strasburg no. 8596, 8 ii 51; Maili, Rogers no num., 11 v 46.

MAUI I., LaPerouse Bay, Doty no. 13187, 17 xii 55; McGregor Point, Matsui & Gilmartin no num., 24 vi 65.

HAWAII I., Kona, Kealakekua, Randall no. 10041, 10 ii 52.

GILBERT ISLANDS

TARAWA ATOLL, Betia, Cooper no. 18823, vii 62 (with several varieties).

MARSHALL ISLANDS

ARNO ATOLL, Ine, Horwitz no. 9047, 10 viii 51.

CAROLINE ISLANDS

TRUK IDS., Dublon I., Meñez no. 273, Nb. 59, 31 vii 60; Fefan I., Meñez no num., 28 vii 60.

YAP I., Yap harbor, Meñez nos. 21985, 23538, 19 viii 60.

PALAU IDS., Iwayama Bay, Meñez no. 361, Nb. 59, 22 viii 60; Peleliu, Doty no. 20530, 23 ix 68.

PHILIPPINE ISLANDS

LUZON I., Albay Prov., Calayucay Bay, Doty & Velasquez no. 10891, 19 v 58; Sorsogon Prov., Bulusan, Santos no.s 20490, 15 v 58, 26771, 3 vi 69; Batangas Prov., Matabungkay, Santos nos. 1306, 20 iii 65, 20449, 3 iv 68; Pangasinan Prov., Lingayan Gulf, Hundred Islands, Doty & Menez no. 16267, 16 ii 58, Alaminos, Cangaluyan Reef, Meñez no. T-1015, 4 ix 67, Cabarruyan I., Anda, Santos no. 20401, 22 ii 68.

CATANDUANES I., Catanduanes Prov., Benticayan Bay, Doty & Velasquez no. 16654, n. d.; Virac Point, Doty & Velasquez nos. 16743, 16744, 20 v 58.

MINDORO I., Mindoro Oriental Prov., Puerto Galera, Doty no. 10909, 2-4 xii 53, Balete Cove, Velasquez no. 5306, 23 iv 62.

SAMAR I., Samar Prov., Guiuan, Santos no. 20465, 26 iv 68, Hinatunglan, Santos nos. 26368, 26421, 15 vi 69.

CEBU I., Cebu Prov., Danao, Pages no. 235, 3 xi 59; Liloan, Pages no. 78, 10 vi 60; Mactan I., Calawisan, Santos no. 26507, 21 vii 71, Beramis Dam, Santos no. 26507, 21 vii 71, *Caulerpa*-farm, Doty & Alvarez no. 14625, n. d.; Olango I., Sta. Rosa, Doty no. 16077, n. d.

PALAWAN ARCHITELAGO, Palawan Prov., Inlulutoc Bay, no coll., no. 5750, 29 iv 64; Cuyo Ids., Cuyo, no. coll., 6000a, 12 v 64, Meñez no. 16536, 30 iv 58, Sandoval-Paras, no. 13066, vi 65.

MINDANAO I., Surigao del Norte Prov., Hinatuan Mawes I., Meñez no. 18005, 7 vii 58; Zamboanga City Prov., Sacol I., Doty & Hair no. 25394, 22 vi 60, Pitogo, Doty & Hair no. 25353, 20 vi 66.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty & Hair no. 25419, 25424, 1966; Tapul Group, Siasi, Sibaud I., Santos nos. 26556, 26558, 14 ix 71, Manubal I., Doty & Hair nos. 25524, Tapaan I., Doty & Hair no. 25568, 10 viii 6; Tawitawi Group, Bilitan I., Doty & Hair nos. 25498, 25500, 25504, 5 viii 66; Sibutu Group, Tumindao I., Sitangkai, Doty & Hair nos. 25450, 25452, 1966.

INDONESIA

JAVA, Bay of Banten, Pulau Dua, Soegiarto no. 8, n.d.

Since this species often grows tightly attached to the exceedingly rough, eroded intertidal rocks characteristic of tropical coral islands, it is commonly difficult to detach, spread out and display

the plants well. In such exposed places they form compact interlaced masses, and do not clearly develop distinctive varietal characters. In fact, plants which grow in relatively quiet water are those which show them. Pacific Caulerpas show features similar to those shown by western Atlantic individuals, although not always the same in range. For the purposes of this list it did not seem wise to attempt to list the varietal type of each collection, although the specimens as they were studied were annotated when appropriate. It may be of interest to point out a few distinctive forms. The last specimen listed, for instance, Soegiarto no. 8, appears to be the var. *corynephora* (Mont.) Weber-van Bosse. The commonest variety of most oceans, var. *clavifera* (Turn.) Weber-van Bosse, seems to be approximated by Bilitan I. no. 25504 and Bulusan no. 20490. Mactan I. no. 26507 may be associated with var. *lamourouxii* (Turn.) Weber-van Bosse. For var. laetevirens (Mont.) Weber-van Bosse we may pick Olango I. no. 16077 and Bilitan I. no. 25498 as reasonable examples. Under var. *occidentalis* (C. Agardh) Børg. may come Andanno. 20401 and Siasi I. no. 26556. Var. *turbinata* (J. Ag.) Eubank (which I have previously called var. *chemnitzia*) shows a wide range of size. Manubal I. no. 25524a and several others seem not too far from the ordinary concept of the variety. However, Guiuan no. 26421 is very much taller than usual, and Bulusan no. 26771 is an extremely lush variant which it would be hard to distinguish from *C. matsueana* Yamada (1944a p. 28), which may not be worthy of specific rank.

Caulerpa selago (Turn.) C. Agardh

PHILIPPINE ISLANDS

SULU ARCHIPELAGO, Sulu Prov., Sibutu Group, Tumindao I., Sitangkai, Doty & Hair no. 25449, 1966.

Caulerpa serrulata (Forssk J. Agardh, var. *serrulata*

HAWAIIAN ISLANDS

OAHU I., Hanouma Bay, Doty no. 10670, 3 v 53; Hanula Park, Doty no. 8661, 22 iv 51; Haleiwa, Fong no. num., 17 i 55.

MAUI I., Kihei, Matsui no. 12874, n. d.

LINE ISLANDS

PALMYRA I., Halstead no. 12190, 27 iv 53; Barren I., Doty no. 18586, 28 xii 59.

GILBERT ISLANDS

TARAWA ATOLL, Betio, Cooper no. 18809A, 18810, vii 62.

CAROLINE ISLANDS

PONAPE IDS., Mantapeitak I., Meñez no. 21543, 20 vi 60.

TRUK IDS., Quoi I., Meñez no. 21014, 2 viii 60.

PHILIPPINE ISLANDS

LUZON I., Sorsogon Prov., Gubut, Villaroya no num., iv 65; Albay Prov., Albay Gulf, Lubas Point, Doty & Velasquez 16846B, 18 v 58; Calayucay Bay, Doty & Velasquez no. 16892, 19 v 58; Quezon Prov., Baler, Digisit, Velasquez 16986, 24 iv 58; Batangas Prov., Matabungkay, Santos no. 1306, 20 iii 65; Pangasinan Prov., Caburruyan (Anda) I., Santos no. 20406b, 22 ii 58.

MINDORO I., Mindoro Oriental Prov., Puerto Galera, Medio Ids., Velasquez no. 3495, 12 v 53.

CEBU I., Cebu Prov., Danao, Sabang, Pages no. 99, 23 xi 60.

MINDANAO I., Zamboanga Prov., Sacol I., Doty & Hair no. 25392, 22 vi 66.

SULU ARCHIPELAGO, Sulu Prov., Tapul Group, Mandubal I., Doty & Hair no num., 10 viii 66; Tawitawi Group, Bilitan I., Doty & Hair no. 25502, 5 viii 66; Sibutu Group, Tumindao I., Sitangkai, Doty & Hair no. 25448, 1966.

Caulerpa serrulata var. *boryana* (J. Agardh) Weber-van Bosse

CAROLINE ISLANDS

PONAPE IDS., Nanmatol I., Meñez no. 23311, 23 vii 60

YAP IDS., Yap, Meñez no. 21853, 18 viii 60.

MARIANAS ISLANDS

SAIPAN I., Maniagassa I., Doty no. 20326, 24 xi 67.

PHILIPPINE ISLANDS

LUZON I., Pangasinan Prov., Hundred Ids., Cuenco I., Cuenco Cave, Doty & Meñez no. 16204, 15 ii 58.

MINDANAO I., Davao Prov., Davao s. of Sasa Wharf, Doty no. 18055, 21 iv 58.

Caulerpa serrulata var. *spiralis* Weber-van Bosse

LINE ISLANDS

PALMYRA I., King no. 10835, 8 i 53; Barren I., Doty no. 18610, Sand I., Doty no. 186211, 29 xii 59.

TUAMOTU ISLANDS

RAROIA ATOLL, Doty & Newhouse no. 11010, 30 vi 52.

SOCIETY ISLANDS

MOPIHA'A I., Sachet no. 992, 8 vii 63.

GILBERT ISLANDS

TARAWA ATOLL, Betio, Cooper no. 18803, vii 62.

MARSHALL ISLANDS

ARNO ATOLL, Arno I., Doty no. 9225, 30 vii 51; reef off Motol-En I., Horwitz no. 9494, 12 viii 51; Kabinlok I., Horwitz no. 9164, n.d.

CAROLINE ISLANDS

PONAPE I., Mantapeitak I., Meñez no. 21678, 20 vi 60.

TRUK IDS., Moen I., Meñez nos. 15885, 29 vii 60, 15926, 1 viii 60.

PHILIPPINE ISLANDS

LUZON I., Sorsogon Prov., Gubat, Villaroya no. 13067, 6 v 65. Batangas Prov., Matabungka, Santos no. 13065, 20 iii 65.

CATANDUANES I., Catanduanes Prov., Benticayan Bay, Doty & Velasquez no. 16653, 21 v 68.

MINDORO I., Mindoro Oriental Prov., Puerto Galera, Uyenco no. 13068, n. d.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty & Hair no. 25417, vi 66.

When the *Caulerpa* materials were studied in Honolulu in 1966 and reviewed in 1967 the *serrulata* specimens were recorded as typical or not distinguishably different, or, as nearer one of two particular varieties. They were not studied again in 1973, and are here reported as annotated in 1966-67. Trono's attempt to separate off a non-

spiralled form (Trono 1973, p. 9, fig. 19) as *C. hummii* Diaz-Pifferer cannot be supported, for various degrees of twisting or flatness are to be found in *C. serrulata*. This is as true in the West Indies as in the Pacific. From the Diaz-Pifferer and Trono illustrations I would certainly place their plants in *C. serrulata*, and, if one wanted a varietal designation, near var. *pectinata* as understood by Mme Weber-van Bosse (1898), near her figures 4-6 on Pl. XXVI. Actually, the illustrations labeled *C. hummii* by these authors are very much closer to the type of *C. serrulata* (as *Fucus serrulatus* Forsskål), a photograph of which is before me, than are the elaborately spiralled forms, such as that illustrated by Trono (1973, fig. 2). The name *C. hummii* Diaz-Pifferer (1969, pp. 12-17) should be placed in the synonymy of *C. serrulata* (Forssk.) J. Ag.

It has been put to me that the difficulty of distinguishing between *C. cupressoides, C. serrulata* and *C. urvilliana* is very great in Pacific material. This may at times be so, and when only dwarfed or abnormally attenuate specimens are available will always be so.

To start with, *C. cupressoides* typically has terete erect axes, and the ramelli are terete, short in some forms, longer in others. When the ramelli are reduced to 3 rows the axis may be less clearly terete than when the ramelli are pluriseriate or irregularly placed. When they are biseriate the ramelli may be quite long, as in *C. cupressoides* var. *lycopodium* fa. *elegans,* or reduced nearly to teeth, as in var. *flabellata*, and then the axis is compressed.

In *C. urvilliana* the erect axes are terete in the stalk part, but become compressed upwardly, and in full development above triangular, where the teeth are triseriate. Ramelli are, then, represented by teeth, not by cylindrical structures. While often somewhat flexuous the axes do not become spiralled.

Also showing the lower axis at least briefly terete, *C. serrulata* axes are flattened above, sometimes broadly, and the margins are dentate. The type specimen is very small, with the flat branch axes not spiralled. The branch axes in this species do range from straight to elaborately spiralled, and in these the teeth may become somewhat dislocated and those on the inner border of the spiral may be reduced or suppressed. The illustrations purporting to be this species in my Bikini book (1950, pl. 30, figs. 1, 2) were incorrectly identified: they are forms of *C. urvilliana*. That on pl. 29, fig. 1 should be referred to *C. serrulata* var. *boryana*: the name used at that time would not satisfy the present rules of nomenclature.

Caulerpa sertularioides (Gmel.) Howe

HAWAIIAN ISLANDS

KAUAI I., Anahola Bay, Doty no. 9998, 2 ii 52; Aliomanu Beach, Doty no. 9923, 3 ii 52.

OAHU I., Mokuleia, Doty no. 12234, 9 xi 52; Kaneohe Bay, Moku-O-Loe I., Doty no. 8115, 3 x 50; Halona, Rogers no num., 3 v 46; Kuapa Pond, Engard no num., 21 iv 43; Mali near Lua-Lua-Lei, Doty no. 8734, 11 iii 51.

GILBERT ISLANDS

TARAWA ATOLL, Betio, Cooper no. 18802, vii 62.

CAROLINE ISLANDS

TRUK IDS., Moen I., Baker Docks, Stone no. 2181, vii 57.

PHILIPPINE ISLANDS

LUZON I., Quezon Prov., Baler, Diksalarin, Velasquez no. 16469, 23 iv 58, Digisit, no. 16985, 24 ix 58; Rizal Prov., Manila Bay, Velasquez no. 5577, 4 ii 64 (excellent), South Harbor, Doty & Menez no. 16297, n. d.; La Union Prov., San Fernando, Almazar no. 1306, 3 iii 65.

CATANDUANES I., Catanduanes Prov., Benticayan, Doty & Velasquez no. 16685b, Virac Point, Doty & Velasquez no. 16471, n. d.

CEBU I., Cebu Prov., Mactan I., Lapu Lapu, Calawisan *Caulerpa*-farm, Doty & Alvarez no. 14626, 4 iv 65.

PALAWAN ARCHIPELAGO, Palawan Prov., Cujo Ids., Cujo I., Menez no. 16539, n. d.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., n. coll., no. 25416, n. d.; Tapul Group, Tapaan I., Doty & Hair no. 25573, 10 viii 66, Tapaan Lagoon, Santos no. 26547, 10 ix 71, Sibaud I., Doty & Hair no. 25564, 10 viii 66.

Both fa. *brevipes* (J. Agardh) Sved. and fa. *longiseta* (Bory) Sved. are represented in this material, though perhaps less distinctively than in Caribbean material. To the former we may assign Kauai no. 9998 and Cujo no. 16539, to the latter Kaneohe Bay no. 8115 and Moen I. no. 2181. The plants from South Harbor no. 6297 showed exceptionally long and slender ramelli, which reach a length of 18 mm.

Caulerpa seuratii Weber-van Bosse

TUAMOTU ARCHIPELAGO

RAROIA ATOLL, Raroia, Doty & Newhouse 11639, 9 viii 52; Oneroa, Boty & Newhouse no. 11499, 29 vii 52 (excellent); Tomongoru (? Tomogagie), Doty & Newhouse no. 11427, 29 vii 52; Teuriamote, Doty & Newhouse no. 11476, 26 vii 52.

Caulerpa taxifolia (Vahl) C. Agardh

CAROLINE ISLANDS

TRUK IDS., Quoi I., Menez no. 23307, 2 viii 60.

YAP I., Menez no. 21897, 18 viii 60.

PHILIPPINE ISLANDS

NEGROS I., Negros Oriental, Siquijor I., Menez T-1138, 28 ix 67, Carrio Solong-on, Santos no. 26187, 26 v 69.

SULU ARCHIPELAGO, Sulu Prov., Mandubal I., Doty & Hair no. 25529a, 10 viii 66.

Dawson's figure 17 (1956, p. 36) I would unhesitatingly ascribe to *C. mexicana* (Sond.) J. Ag. The broad axes, with the ramelli clearly contracted toward the base, are characteristic.

Caulerpa urvilliana Mont., var. *urvilliana*

LINE ISLANDS

PALMYRA I., Sand I., Doty no. 186211, 29 xii 59.

FANNING I., North Pass, Wainwright no num., n. d.; Tempua, Wainwright no. 20101, n. d., Greig Point, DeWreede no. 1222 *p.p.*, 5 i 70.

TUAMOTU ARCHIPELAGO

RAROIA ATOLL, Kukina, Doty & Newhouse no. 11454, 3 vii 52; between Temari and Kumekume, Doty & Newhouse no. 11021, 1 vii 52.

MARSHALL ISLANDS

ARNO ATOLL, Ine Village, Horwitz no. 9044, 10 vii 51.

CAROLINE ISLANDS

PINGELAP I., Meñez nos. 21454, 21925, 1 vii 60.

MOKIL IDS., Urak I., Meñez nos. 21227, 21285, 21360, 29 vi 60.

TRUK IDS., Quoi I., Meñez no. 21602, 2 viii 60.

IFALUK IDS., Ifaluk I., Meñez nos. 23111, 23126, 10 viii 60; Ella I., Meñez no. 23230, 10 viii 60.

YAP I., south of the channel, Meñez nos. 21567, 15817 (very good), 19 viii 60, north of the channel, no. 21896, 18 viii 60.

PALAU IDS., Peleliu I., Doty no. 20529, 23 xi 68.

HELEN I., west side, Meñez nos. 15480, 15519, 15537, 30 vii 60, Helen Island Reef, Meñez no. 15390, 28-30 viii 60.

PHILIPPINE ISLANDS

LUZON I., Sorsogon Prov., Bulusan, Santos no. 20513 *p.p.*, 17 v 68..

NEGROS I., Negros Oriental Prov., Siquijor I., Carrio Solong-on, Meñez no. 1135, 28 ix 67, Santos nos. 26208, 26055 (very good). Tending toward v. *vitiensis,* Alcala no. 20518, 28 v - 29 vi 68, Santos nos. 26041, 26182, 22 v 69.

PALAWAN ARCHIPELAGO, Palawan Prov., Cujo Ids., Cuyo, no coll., no. 16540, 30 iv 58.

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty & Hair, no. 25447, vi 66; Tapul Group, s. of Siasi I., Doty & Hair no. 25529b, 10 viii 66; Tapaan I., Trono no. T-4077, 29 xii 70; Tawitawi Group, Tawitawi I., Balimbing Point, Meñez no. T-1101, 23 ix 67.

Caulerpa urvilliana var. *vitiensis* (Sond.) Weber-van Bosse

TUAMOTU ARCHIPELAGO

RAROIA ATOLL, Ohehoa, Doty & Newhouse no. 11503, 2 viii 57 (excellent).

PHILIPPINE ISLANDS

SULU ARCHIPELAGO, Sulu Prov., Jolo Group, Pangasinan I., Doty no. 25422, vi 66.

Caulerpa verticillata J. Agardh

HAWAIIAN ISLANDS

OAHU I., Kaneohe Bay, Moku-O-Loe (Coconut) Island, Doty no. 8117, 3 x 50 (excellent), Jones no. 10433, 7 i 52, Wainwright no num., 17 vii 59, Buggeln & Tsuda no. 14186, 15 vi 64, Littler no. 20539, 10 x 68.

CAROLINE ISLANDS
PONAPE.,
MANTAPEITAK I., Meñez no. 23409, 20 vi 60.
KOLONIA I., mud flats toward Sokehs I., Meñez no. 21108, 25 vi 60
PHILIPPINE ISLANDS
CEBU I., Cebu Prov., Davao Bay, Boty & Alvarez no. 14350, 3 ii 65; Mactan I., Calawisan, Meñez no. T-1029, 6 ix 67.
NEGROS I., Negros Oriental Prov., Siquijor I., Carrio Solong-on, Santos no. 26161, 26 v 69.

Caulerpa webbiana Mont.

HAWAIIAN ISLANDS
LAYSAN I., Tsuda no num., 6 xii 63.
KAUAI I., Kuaehu Point, Abbott no num., 21 ii 46.
OAHU I., Mokuleia, Doty no. 12233, 9 xi 52; Laie, Doty no. 19287, 30 i 60; Waikiki, Doty no. 8260, 3 xi 50; Lua-Lua-Lei, Maili, Doty no. 8733.
EASTER ISLAND, Hotuiti, Matsui no. 20671, 3 iv 69.
MARSHALL ISLANDS
ARNO ATOLL, Enen Edrik I., Horwitz no. 9032, 7 vii 51.

References

Abbott, I.A. 1961. A check list of marine algae from Ifaluk Atoll, Caroline Islands. *Atoll Res. Bull.* 77: 1-5.

Børgesen, F. 1913. The marine algae of the Danish West Indies. I. Chlorophyceae. *Dansk Bot. Arkiv,* 1(4): 1-158 + 2, 126 figs., map.

Dawson, E.Y. 1956. Some marine algae of the Southern Marshall Islands. *Pacific Sci.* 10(1): 25-66, 66 text-figs.

Dawson, E.Y. 1957. An annotated list of marine algae from Eniwetok Atoll, Marshall Islands. *Pacific Sci.* 11: 92-132, 31 text-figs.

Diaz-Pifferer, M. 1969. *Caulerpa hummii,* a new species of marine algae (Chlorophyta, Caulerpales) from Venezuela. *Phycologia* 7(1): 12-17.

Gilbert, W.J. 1942. Notes on *Caulerpa* from Java and the Philippines. *Pap. Michigan Acad. Sci., Arts & Lett.* 27: 7-26, 5 text-figs.

Gilbert, W.J. 1946. Philippine Chlorophyceae II. *Bull. Torr. Bot. Club* 73(1): 73-99.

Gilbert, W.J. 1961. An annotated checklist of Philippine marine Chlorophyta. *Philippine Journ. Sci.* 88(4): 413-451, 1 text-fig., 1 pl. (1959).

231-339 O - '77 - 2

Gilbert, W.J. 1962. Contribution to the marine Chlorophyta of Hawaii, I. *Pacific Sci.* 135-144, 8 text-figs.

May, V. 1953. Some marine algae from New Caledonia collected by Mrs. R. Catala. *Contr. New South Wales Nat. Herb.* 2(1): 36-66.

May, V. 1966a. Algae of the Gilbert Islands. *Contr. New South Wales Nat. Herb.* 4(1): 13-16.

May, V. 1966. Further records of algae from New Caledonia collected by Mrs. R. Catala. *Contr. New South Wales Nat. Herb.* 4(1): 17-18.

Okamura, K. 1916. List of marine algae collected in the Caroline and Mariana Islands, 1915. *Bot. Mag. Tokyo* 30: 1-14, 9 text figs., 1 pl.

Taylor, Wm. Randolph. 1950. *Plants of Bikini.* xv + 227 + 1 pp., frontisp., 79 pl. Univ. Mich. Press, Ann Arbor.

Taylor, Wm. Randolph. 1966. Records of Asian and Western Pacific marine algae, particularly from Indonesia and the Philippines. *Pacific Sci.* 20(3): 342-359. 2 text-figs.

Taylor, Wm. Randolph. 1973. Marine algae of the Smithsonian-Bredin Expedition to the Society and Tuamoto Islands. *Pacific Sci.* 27(1): 37-43, 11 text-figs.

Trono, G.C. 1968. The marine benthic algae of the Caroline Islands, I. Introduction, Chlorophyta, and Cyanophyta. *Micronesica* 4(2): 137-206, 19 pls.

Trono, G.C. 1972a. Notes on some marine benthic algae in the Philippines. *Kalikasan Philippine Journ. Biol.* 1: 126-147, 21 figs.

Trono, G.C. 1972b. The marine benthic algae of Siasi Island and vicinity. I. Introduction and Chlorophyta. *Kalikasan Philippine Journ. Biol.* 1: 207-228.

Trono, G.C. 1973. Studies on the marine benthic Chlorophyta of Puerto Galera, Oriental Mindoro, Philippines. *Univ. Philip. Nat. Sci. Res. Center, Techn. Rep.* 1: 1-25, 24 text-figs.

Tsuda, R.T. & Belk, M.S. 1972. Additional records of benthic algae from Yap, Western Caroline Islands. *Atoll Res. Bull.* 156: 1-5.

Yamada, Y. 1941. Species of *Caulerpa* in the South Sea. *Kagaku Nanyo* 4: 95-105, 16 text-figs.

Yamada, Y. 1944a. New Caulerpas and Halimedas from Micronesia. *Sci. Pap. Inst. Algol. Res. Hokkaido Univ.* 3(1): 27-29, pls. 1-5.

Yamada, Y. 1944b. A list of the marine algae from the Atoll of Ant. *Sci. Pap. Inst. Algol. Res. Hokkaido Univ.* 3(1): 31-45, pls. 6, 7.

Weber-van Bosse, A.A. 1898. Monographie des Caulerpes. *Ann. Jard. Bot. Buitenzorg,* 15: 243-401, pls. 20-34.

Weber-van Bosse, A.A. 1910. Note sur les *Caulerpa* de l'île Taïti et sur un nouveau *Caulerpa* de la Nouvelle-Hollande. *Ann. de l'Inst. Océanogr.* 2: 1-8, pl. 1, 2.

Womersley, H.B.S. and Bailey, A. 1970. Marine algae of the Solomon Islands. *Philos. Trans. Roy. Soc., B, Biol. Sci.* 259: 257-352, pls. 24-27, 10 text-figs.

ATOLL RESEARCH BULLETIN
NO. 209

MARINE ALGAE OF THE TE VEGA 1965 EXPEDITION IN THE WESTERN PACIFIC OCEAN

by Wm. Randolph Taylor

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

MARINE ALGAE OF THE TE VEGA 1965 EXPEDITION IN THE WESTERN PACIFIC OCEAN

by Wm. Randolph Taylor [1]

The widespread interest in oceanography currently developing has revived the practice of research cruises, but these have generally been devoted to problems of the open ocean rather than of the shoreline, the littoral and sublittoral. The marine institutes of both Atlantic and Pacific coasts of North America have been most active in this open sea work. It is particularly noteworthy that one series promoted by Leland Stanford Jr. University with the M/V *Te Vega* did afford opportunity for work in shallow water along shore.[2] Professor Lawrence R. Blinks, Director of the Hopkins Marine Station of that University was Chief Scientist for the 1965 cruise with which this report is concerned, and the algal material was collected by Dr. Charles F. Cleland, then at Stanford University.[3] The writer is greatly indebted to him for the opportunity to study the material, which was accompanied by extensive field notes and partial identification. For the most part these data could only have been fully utilized by the person who had done the work in the field, but the

---

[1] Department of Botany, University of Michigan.

[2] The field work of this M/V *Te Vega* cruise of the winter of 1965 was conducted under National Science Foundation Grant no. G-17465 to Stanford University. Part of the laboratory research on the algae was done under National Science Foundation Grant no. GB-3186 to the University of Michigan. For these supporting grants the collector and the writer are most grateful. A selection of voucher specimens has been placed in the Herbarium of the University of Michigan and the balance returned to the collector.

[3] Present address: Smithsonian Radiation Biology Laboratory, 12441 Parklawn Drive, Rockville, Maryland 20852.

(Manuscript received April 1974 -- Eds.)

general characters of the stations are outlined on following pages, based on the notes provided. Unfortunately much time has elapsed since the material was collected and the large proportion which was in formaldehyde has suffered accordingly; nevertheless much of value remained and it is possible now to give a report in which a large proportion of records are new for the areas concerned. So far as these collections are concerned, the reports start with observations near Singapore, swing up past northern Borneo and through the southern Philippines, then down through the Bismark Archipelago to New Britain Island, over to Bougainville Island in the Solomon Islands, with the last sampling from Guadalcanal Island.

The stations visited by the Te Vega Expedition in question are so distant from each other that a thorough review of the pertinent phytogeographical literature is impracticable. Most curiously, Singapore, which has been a famous botanical center for many decades has never been favored with a major published algal flora, although the former Director of the Botanical Garden, Dr. H.M. Burkill, collected there extensively, and so the first station, the nearby Hantu Island, has no marine phycological history. Nevertheless, the Siboga Expedition reports of Mme A. Weber-van Bosse (1913-1923) apply very well, even though ranging far to the east of Indonesia.

There have been several papers on Philippine marine algae, summarized by me (1966) and supplemented by others, as Trono (1972). The Caroline Islands have been visited by E.G. Meñez and reported upon by Trono (1968, 1969), and Tsuda both collected there and reported his results (1972). The Bismark Archipelago has less algal history. The Zaca Expedition collected in the Solomon and Santa Cruz Islands in 1933 and Setchell reported on the plants (1935), while the Solomons have had the benefit of a recent study by Womersley (1969, 1970). Chapman has recently published on the algae of Fiji (1971). Setchell (1924) dealt with the algae of Samoa. The Society and Tuamotu island groups far to the east have been visited several times: Setchell reported on Tahitian algae (1926) and those collected by a Smithsonian Institution group in 1957 were studied by me (1973). While very much to the north of the Te Vega Expedition route, the algal flora of the Marshall Islands shows much similarity, and my account (1950) and those of Dawson (1956, 1957) are useful for consultation.

From the literature cited in these papers a fairly complete idea of the Indonesian-Polynesian marine flora can be obtained, and it leads one to a wealth of minor scattered records. In addition, the bibliographic compilations of Walker (1947) and of Trono (1966) must be considered. When all this is taken into account it seems clear that the information on the algal flora of this vast area is still too fragmentary to justify any firm conclusions as to floristic trends, although attempts were early made to do this (Weber-van Bosse 1913-1923; Yamada 1926).

List of Stations

Station 1. 16 I 1965

MALAYSIA, Pulau Hantu. An islet 11-16 km west of Singapore, off the Malay Peninsula.

The area studied was in general a firm but silty shoal, with scattered rocks exposed, and a few mangroves. The dominant alga reported was *Sargassum*, but none was collected. A bit higher *Turbinaria conoides* was prominent, and *Bryopsis pennata* seems to have been frequent on these coarse algae. Various small species were collected, but none seemed to occur in conspicuous communities. Interesting genera include *Microdictyon, Bornetella, Martensia* and *Tolypiocladia*. Notable near high tide line were communities of *Halophila ovalis* (R. Br.) J.D. Hooker, a widespread marine phanerogam.

Station 2. 23 I 1965

SOUTH CHINA SEA at about 1° 47' N.L., 107° 47' E.L.

A few floating algae were collected, mostly *Sargassum* and its epiphytes, none in conspicuous quantity.

Station 3. 24 I 1965

SOUTH CHINA SEA at about 2° 31' N.L., 110° 42' E.L.

This was a small collection from floating material, basically portions of *Sargassum* plants with some epiphytes.

Station 4. 26 I 1965

SOUTH CHINA SEA at about 6° 33' N.L., 115° 51' E.L.

This sample was reported to have had a few more items than had Sta. 3, but *Leveillea jungermannioides* and *Sphacelaria furcigera* were the most common epiphytes on the *Sargassum,* and only these species yielded voucher specimens.

Stations 6, 7. 31 I 1965

MALAYSIA, Pulau Gaya area. These stations were in a complex of islands off the east coast of North Borneo.

Station 6 is on the west side of Pulau Mantabuan. The aspect is reported to be one of sparse vegetation over a sandy bottom. The chief alga seems to have been *Enteromorpha lingulata,* but various other things were here or at Station 7, mostly *Champia parvula* and *Laurencia papillosa*. While the *Champia* might have been an epiphyte, the other

things probably grew on rocks and shells exposed above the sand. Station 7, off the south side of Pulau Gaya nearby, is reported to have involved a reef of live corals nearly free of algal colonies, though a little *Halimeda opuntia* was noted, but not collected.

Stations 8-10. 31 I to 6 II 1965

MALAYSIA, Pulau Gaya area.

Station 8 consisted of a shoal sand-spit between two islands, part of the crest being barely uncovered at low water, and part of the shore of Pulau Tatagan nearby. Pieces of shell and dead coral lay about and live corals became more abundant as one moved into deeper water. The vegetation involved a conspicuous mat of *Valonia aegagropila* over which the water, 1.8-2.4 meters deep, was at times found to reach a temperature of 38°C. *Dictyosphaeria cavernosa* was common and grew especially well in the shelter of the *Valonia* and other larger algae. *Valonia ventricosa* was also notable here, and one large individual displaced 90 ml. *Spongocladia dichotoma,* a most curious plant, was also notable here. A little deeper, scattered rocks bore a good vegetation of the very common *Halimeda opuntia, H. macroloba,* several Caulerpas and *Microdictyon montagnei*. Patches of turtle-grass, *Enhalus acoroides* (L., f.) Royle, showed colonies of *Padina* associated with it.

Station 9. 31 I to 6 II 1965

MALAYSIA, Pulau Gaya area, Pulau Tatagan.

This material is chiefly from one of the islets adjoining Station 8, with which collection the material was bottled, and it involved part of the north shore of the sand spit. The islet was fairly rich in algae along the northwest side. Here *Caulerpa racemosa* and *Dictyota dichotoma* were common on the scattered rocks, where also there was quite a bit of *Chlorodesmis comosa*. Mangrove roots near shore carried *Lobophora variegata* and smaller epiphytes. *Halophila ovalis* was quite common on the sandy areas, and a variety of *Caulerpa mexicana* was found with it.

Station 10. 4, 5 II 1965

MALAYSIA, Pulau Gaya.

Collections were made progressively along the shoal and beyond the collection Stations 8, 9, and thus beyond the *Valonia aegagropila* community. There were occasional rocks and broken coral masses here. On the lower sides of them and not found elsewhere, appeared *Caulerpa verticillata* and *Udotea javensis*. *Valonia ventricosa* plants grew in some numbers on dead coral: *Spongiocladia dichotoma* grew rather abundantly in a few patches on old coral near shore, and *Dictyosphaeria cavernosa* was common where somewhat shaded, while in

deepest shade *D. versluysii* also occurred. In the sand *Avrainvillea erecta* was common. *Caloglossa* is reported on mangrove roots near the end of the route, but did not appear among the specimens preserved. This was a station with a relatively richly varied flora.

Station 11. 4, 5 II 1965

MALAYSIA, Pulau Gaya area, Pulau Mantabuan.

This collection was made off a sandy beach south of the pearling station. *Avrainvillea erecta* was again common. One large clump of *Hydroclathrus clathratus* was seen.

Stations 12, 12a. 6 II 1965

MALAYSIA, Pulau Gaya area, Pulau Mantabuan.

On the south side there was a community of *Valonia aegagropila* and associates similar to that of Station 9. On the north and west a broad sandy flat with patches of turtle-grass was bounded outside by patches of coral, beyond which there is a deeper lagoon-like zone about a meter deep at low tide, where there was a rather different flora from that elsewhere. It especially consisted of genera favoring sheltered water, such as *Hypnea, Ceramium, Champia, Spyridia, Centroceras,* and *Tolypiocladia.* The broken coral reef bordering this on the seaward side had a heavy growth of *Enteromorpha clathrata, Trichosolen* and *Polysiphonia.*

Station 13. 13 II 1965

PHILIPPINES, Mindanao Island, Zamboanga, off Zamboanga City.

This station involved a small offshore islet and lagoon. *Ulva reticulata* was very abundant on the sandy bottom, and *Cladophoropsis philippinensis* with *Valonia aegagropila* formed large masses with it. *Boergesenia* was reported as common on the bottom, but no voucher specimens were received.

Station 14. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul area.

This station was on the north side of Crater Peninsula opposite the town of Rabaul. *Sargassum cristaefolium* in quantity, and *Galaxaura oblongata* were found here, washed ashore.

Station 15. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul.

This material was collected from a small, rocky island in Rabaul

Harbor. On the rubble of dead corals and rocks there were a few scraps of algae, but only *Actinotrichia rigida* was in fair condition. By diving *Galaxaura veprecula* was obtained from a depth of about 20 meters.

Station 16. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul area, Duke of York Islands.

A general and rather varied collection, some 17 species being represented in the material recovered, reflecting the variety of areas concerned. The species of *Halimeda* were the most noteworthy elements, but large plants of *Valonia ventricosa* with a displacement up to 75 ml. seem to have been prominent. There were 3 Caulerpas, and the occurrence of large plants of *Udotea argentea* was notable.

Station 17. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul harbor.

On an old ship hull there was a growth of *Caulerpa serrulata,* and some *Bryopsis* which was not preserved.

Station 18. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul, Matupi I.

This station involved a turtle-grass bed of *Cymodocea serrulata* (R. Br.) Asch. & Magn. and *Halodule univervis* (Forssk.) Asch., with associated *Halophila ovalis,* in 1.2-2.4 meters' depth of water. It yielded more *Udotea argentea, Dictyopteris repens* and several little things, such as *Neomeris annulata, Acetabularia major* and *Sphacelaria tribuloides.*

Station 19. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul.

On a coral patch at this station there was some *Caulerpa serrulata,* and on exposed rocks *Turbinaria ornata* was reported but without voucher specimens.

Station 20. 26 II-4 III 1965

BISMARK ARCHIPELAGO, New Britain Island, Rabaul area.

On the shore of Point Gazelle 16-32 km south of Rabaul there was a collecting area with considerable surf, where at depths of 0.3-1.0 meter *Chlorodesmis comosa, Hydroclathrus clathratus* and *Ceratodictyon spongiosum* were found. *Boergesenia forbesii* was reported very common in a narrow zone at a depth of about 0.3 m.

Station 21. 8 III-15 III 1965

SOLOMON ISLANDS, Bougainville Island, Kieta area, Puk Puk Islet.

This collection was made on a protected southern point with *Sargassum* and *Padina australis* growing on hard objects over the sand or on patches of coral reef at depths of 0.6-1.8 meters. There were many smaller things in addition. Most notable for this station were *Chlorodesmis comosa, Neomeris dumetosa,* and the spectacular *Halymenia durvillaei*.

Station 22. 8 III-15 III 1965

SOLOMON ISLANDS, Bougainville Island, Kieta area, Puk Puk Islet.

While made from the east side of the islet the vegetation was similar, but because of the lack of segregation of the Kieta area materials little beyond *Galaxaura apiculata* could be directly attributed to it.

Station 23. 8 III-15 III 1965

SOLOMON ISLANDS, Bougainville Island, Kieta area.

The material of this collection came from the fringing reef several miles from shore, separated from it by deep water and exposed to moderate-to-heavy surf. Inside this was a lagoon-like area with much dead coral and a sandy shoal, free from surf but with substantial surge currents. For this area most notable was *Tydemannia expeditionis* which was present in quantity, a splendid acquisition. *Caulerpa pickeringii* among the 4 Caulerpas found was less showy, but almost as important. *Halimeda incrassata* and *H. micronesica* occurred here. Stations 21 and 23 each yielded about 20 species of algae.

Stations 25, 26. 8 III-15 III 1965

SOLOMON ISLANDS, Bougainville Island, Kieta area, near Marowa Point.

This material came from the first point east of Marowa Point. This was exposed to moderate surf. Many of the algae were growing in shade, due to the neighboring cliff with overhanging vegetation. The substrate was rock, more or less sand-covered, and corals were absent. Halimedas were reported in evidence, but not collected; *Cladophoropsis ? zollingeri* formed extensive mats. *Chnoospora minima* in a small form was the only conspicuous brown alga. *Actinotrichia rigida* was frequent on the rocks, as were *Galaxaura squalida* and *G. apiculata*.

Station 27. 21 III 1965

SOLOMON ISLANDS, Guadalcanal Island, Kamembo Reef.

This station was 16-32 km north of Honiara. A companion on the

expedition contributed to the Cleland collections a small plant of *Halymenia durvillaei* from this station, found on a coral head at a depth of 3.0-4.5 m.

List of species[4]

CHLOROPHYCEAE

ULVALES

Ulvaceae

Enteromorpha lingulata J. Agardh MALAYSIA, Pulau Gaya area, Stas. 6, 12.

Enteromorpha clathrata (Roth) J. Agardh Pulau Gaya area, Sta. 12.

Ulva reticulata Forssk. PHILIPPINES, Mindanao I., Sta. 13.

CLADOPHORALES

Cladophoraceae

Chaetomorpha crassa (C. Agardh) Kütz. Mindanao I., Sta. 13.

Chaetomorpha linum (Müll.) Kütz. SOLOMON ISLANDS, Bougainville I., Sta. 21.

Rhizoclonium hookeri Kütz. Pulau Gaya area, Sta. 9; Bougainville I., Sta. 25.
Filaments in this material range from 35 μm to 100 μm, and so cover the widest range I have ascribed to the species.

Cladophora sp. Material of this genus was not a feature of these collections, though a small specimen which I could not assign to any species, did occur in the Pulau Gaya area material.

SIPHONOCLADIALES

Dasycladaceae

Neomeris annulata Dickie BISMARK ARCHIPELAGO, New Britain I., Sta. 18.

Neomeris dumetosa Lamx. MALAYSIA, Pulau Hantu, Sta. 1; Bougainville I., Sta. 21.

Bornetella oligospora Solms-Laub. Pulau Hantu, Sta. 1.

Acetabularia major Solms-Laub. New Britain I., Sta. 18.

Acetabularia parvula Solms-Laub. Pulau Gaya area, Sta. 10; Bougainville I., Sta. 21.

Valoniaceae

Valonia aegagropila C. Agardh Pulau Gaya area, Stas. 8-10; Mindanao I., Sta. 13; Bougainville I., Stas. 21, 25.

Valonia ventricosa J. Agardh Pulau Gaya area, Stas. 8, 10; New Britain I. area, Duke of York Islands, Sta. 16; Bougainville I., Stas. 21, 22.

---

[4] In listing the localities where the various species were found the name of the general area: PHILIPPINES, SOLOMON ISLANDS, etc., will be given only at the first appropriate place, since, like the detailed site characterization, it can be ascertained through the station number in the preceding descriptions of localities.

Boergesenia forbesii (Harv.) Feldm. Pulau Gaya area, Stas. 8, 9; New Britain I., Sta. 20; Bougainville I., Sta. 25.

Valoniopsis pachynema (Mart.) Børg. Bougainville I., Sta. 25.

Dictyosphaeria cavernosa (Forssk.) Børg. Pulau Hantu, Sta. 1; Pulau Gaya area, Stas. 8, 10.

Dictyosphaeria versluysii Weber-van Bosse. Pulau Gaya area, Sta. 10; New Britain I., Stas. 21, 22.

Cladophoropsis philippinensis W.R. Taylor. Mindanao I., Sta. 13.

Cladophoropsis zollingeri (Kütz.) Borg.? Bougainville I., Sta. 25.

Spongocladia dichotoma (Zan.) Murr. & Bood. Pulau Gaya area, Sta. 10.

Microdictyon montagnei Harv. Pulau Hantu, Sta. 1; adrift, South China Sea, Sta. 2; Pulau Gaya area, Sta. 8.

Anadyomene plicata Zan. Duke of York Ids., Sta. 16; Bougainville I., Stas. 21, 23, 25.

Anadyomene wrightii Gray. Bougainville I., Sta. 23.

SIPHONALES

Bryopsidaceae

Bryopsis pennata Lamx. Pulau Hantu, Sta. 1; New Britain I., Sta. 17; Bougainville I., Stas. 21, 23.

Trichosolen parva (Dawson) Taylor Pulau Gaya, Sta. 12. These plants were 1-2 cm tall, taller than those reported by Dawson from Viêt Nam (1954, p. 393) and more densely clothed with ramelli, but the dimensions of axes and ramelli, the shape and range of measurements of the gametangia are close. Certainly in view of the little we know of the range of variation in the genus one had best regard these plants as a relatively luxuriant form of *T. parva*.

Caulerpaceae

Caulerpa ambigua Okam. Bougainville I., Sta. 21.

Caulerpa lentillifera J. Agardh. Pulau Gaya area, Sta. 9; Duke of York Ids., Sta. 16.

Caulerpa lessonii Bory. Pulau Gaya area, Sta. 8.

Caulerpa peltata (Lamx.) Weber-van Bosse. Pulau Gaya area, Stas. 9, 12; New Britain I. area, Sta. 16; Bougainville I., Sta. 23.

Caulerpa pickeringii Harv. & Bail. Bougainville I., Sta. 23.

Caulerpa racemosa (Forssk.) Weber-van Bosse Pulau Gaya area, Stas. 8, 10; Duke of York Ids., Sta. 16; Bougainville I., Sta. 23.

Caulerpa serrulata (Forssk.) J. Agardh. Pulau Hantu, Sta. 1; Pulau Gaya area, Stas. 8, 10; New Britain I., Stas. 17, 19; Bougainville I., Sta. 21.

Caulerpa sertularioides (Gmel.) Howe Pulau Gaya area, Stas. 8, 9.

Caulerpa taxifolia (Vahl) C. Agardh ? Pulau Gaya area, Sta. 9.

Caulerpa urvilliana Mont. Duke of York Ids., Sta. 16.

Caulerpa verticillata J. Agardh. Pulau Gaya area, Sta. 10.

Codiaceae

Chlorodesmis comosa Bail. & Harv. Pulau Gaya area, Sta. 9; New Britain I., Sta. 20; Bougainville I., Sta. 21.

Avrainvillea erecta (Berk.) A. & E. S. Gepp. Pulau Gaya area, Stas. 8, 9.

Avrainvillea lacerata J. Agardh. Bougainville I., Sta. 23.

Tydemannia expeditionis Weber-van Bosse. Bougainville I., Sta. 23.

Udotea argentea Zan. Duke of York Islands, Sta. 16; New Britain I., Sta. 18.

Udotea javensis (Mont.) A. & E. S. Gepp Pulau Gaya area, Sta. 10; Bougainville I., Sta. 21.

Codium tenue Kütz. Rabaul, Sta. 15; Duke of York Ids., Sta. 16; Kieta, Sta. 23.

Halimeda cylindrica Decne. Duke of York Ids., Sta. 16; New Britain I., Stas. 18, 19.

Halimeda discoidea Decne. Pulau Gaya area, Sta. 9; Bougainville I., Sta. 21.

Halimeda incrassata (Ell.) Lamx. Bougainville I., Sta. 23.

Halimeda macroloba Decne. Pulau Hantu, Sta. 1; Pulau Gaya area, Sta. 8; Duke of York Ids., Sta. 16.

Halimeda micronesica Yam. Bougainville I., Sta. 23.

Halimeda opuntia (L.) Lamx. Pulau Hantu Sta. 1; Pulau Gaya area, Stas. 8, 9; Mindanao I., Sta. 13; New Britain I., Sta. 15; Duke of York Ids., Sta. 16; Bougainville I., Stas. 21, 23.

PHAEOPHYCEAE

SPHACELARIALES

Sphacelariaceae

Sphacelaria furcigera Kütz. South China Sea, Sta. 4.

Sphacelaria novae-hollandiae Sond. Bougainville I., Sta. 23.

Sphacelaria tribuloides Menegh. New Britain I., Sta. 18; Bougainville I., Sta. 21.

DICTYOTALES

Dictyotaceae

Dictyota apiculata J. Agardh, var. *jedanensis* Weber-van Bosse? Pulau Gaya area, Stas. 8, 12.

Dictyota ceylonica Kütz., var. *rotundata* Weber-van Bosse? Pulau Gaya area, Sta. 12.

Dictyota dichotoma (Huds.) Lamx. Pulau Hantu, Sta. 1; Pulau Gaya area, Sta. 9; Duke of York Ids., Sta. 16; Bougainville I., Sta. 23.

Dictyota divaricata Lamx.? Pulau Gaya area, Sta. 12; Duke of York Ids., Sta. 16.

Dictyopteris repens (Okam.) Børg. New Britain I., Sta. 18; Bougainville I., Sta. 21.

Padina australis Hauck Pulau Hantu I., Sta. 1; New Britain I., Sta. 18; Bougainville I., Sta. 21.

"*Dictyerpa*" or "*Vaughniella*" phase of *Padina*. Pulau Gaya area, Stas. 9, 10; Mindanao I., Sta. 13; Bougainville I., Sta. 23. Some of the *P. australis* material is transitional from this phase.

Lobophora variegata (Lamx.) Womersl. Pulau Gaya area, Stas. 9, 10; Bougainville I., Sta. 23.

PUNCTARIALES

Asperococcaceae

Chnoospora minima (Her.) Papenf. Bougainville I., Sta. 26.

Hydroclathrus clathratus (Bory) Howe Pulau Gaya area, Stas. 8, 10; New Britain I., Sta. 20.

FUCALES

Sargassaceae

Sargassum. Several specimens of *Sargassum* in the Cleland material defied identification with the reference materials available, *S. cristaefolium* and *S. swartzii* being the ones clearly recognizable. The best that I can do at present is to suggest the possible relationships of the more distinctive of them. In addition to the 6 doubtful ones, other pieces in the collection may be variants of these, or may be other less distinctive forms.

Sargassum capillare Kütz.? Pulau Gaya area, Pulau Mantabuan, Sta. 12a. Tall, exceeding 6.5 dm, much branched, the axes terete, nearly smooth. The leaves crowded on the lateral branches, about 2 mm broad, 10 mm long, linear-lanceolate, the margins sharply serrate, elaborately proliferous, as to lesser degrees are the leaf faces, the stems and the vesicles. Cryptostomata few, on each side of the subpercurrent costas. Vesicles small, short-stalked. Receptacles sparingly forked, exceeding the leaves.

Sargassum cristaefolium C. Agardh New Britain Island, Sta. 14.

Sargassum myriocystum J. Agardh ? Pulau Gaya, Sta. 9. To 2 dm tall, the axes terete, densely spinulose. The leaves to about 7 mm broad, 30 mm long, broadly lanceolate, the costae percurrent, the leaf margins erose-dentate, the cryptostomata small, numerous, scattered.

Sargassum ornatum Grev.? Adrift, South China Sea, Sta. 3. To at least 3 dm tall, the axes terete, smooth. The leaves crowded on the lateral branches, to 5 mm broad, 35 mm long, oblong-ovate, broad to the rounded apex, sharply serrate. Costa not reaching to the leaf tip; cryptostomata small, numerous, scattered. Vesicles short-stalked, short oval, apiculate.

Sargassum polycystum J. Agardh ? Adrift, South China Sea, Sta. 2. Plants very delicate, the terete axes spinulose. The leaves chiefly on the upper axes and the outer parts of the lateral branches, small, about 2.0-2.5 mm broad, 1 cm long, lanceolate, strongly serrate. Costa subpercurrent; cryptostomata few, somewhat irregularly dispersed.

Sargassum swartzii (Turn.) J. Agardh Adrift, South China Sea, Sta. 2. Plants to at least 3 dm tall, the stems flat, smooth. The leaves to 3.0-3.5 cm long, narrowly lanceolate, long-attenuate, shallowly dentate. Costa percurrent, with the cryptostomata in an irregular row on each side. Vesicles large, spherical.

231-339 O - '77 - 3

Sargassum sp. Bougainville I., Kieta area, Sta. 22. About 3 dm tall, much branched, the stems terete, smooth. The leaves rather crowded, small, to 2.5 mm broad, 12 mm long, narrow, acute, sharply dentate. Costa inconspicuous, about 0.6 the length of the leaf; cryptostomata rather numerous, scattered on each side of the costa. Vesicles numerous, very small, round to oval, frequently apiculate.

Turbinaria condensata Sond., prox. Pulau Gaya area, Sta. 10.

Turbinaria conoides J. Agardh Pulau Hantu, Sta. 1; Pulau Gaya area, Sta. 10.

Turbinaria marrayana Bart. New Britain I., Sta. 20.

Turbinaria ornata (Turn.) J. Agardh Bougainville I., Sta. 21.

RHODOPHYCEAE

BANGIALES

Bangiaceae

Erythrotrichia carnea (Dillw.) J. Agardh Pulau Gaya area, with *Trichosolen,* Sta. 12.

NEMALIONALES

Chaetangiaceae

Actinotrichia rigida (Lamx.) Decne. New Britain I., Sta. 15; Bougainville I., Stas. 21, 25.

Galaxaura apiculata Kjellm. Bougainville I., Stas. 22, 25.

Galaxaura fasciculata Kjellm., prox. Bougainville I., Sta. 21.

Galaxaura oblongata (Sol.) Lamx. New Britain I., Sta. 14.

Galaxaura squalida Kjellm. Bougainville I., Sta. 25.

Galaxaura ventricosa Kjellm. New Britain I., Sta. 15. This material agrees well with the description of *G. ventricosa*, except that the marginal spinulose cells were minutely apiculate.

CRYPTONEMIALES

Rhizophyllidaceae

Desmia hornemanni Lyngb. Bougainville I., Sta. 23.

Corallinaceae

Fosliella farinosa (Lamx.) Howe Pulau Gaya area, Sta. 12; Duke of York Ids., Sta. 16.

Lithophyllum moluccense Fosl. Bougainville I., Sta. 23.

Amphiroa anceps (Lamk.) Decne. Bougainville I., Sta. 23.

Amphiroa foliacea Lamx. New Britain I., Sta. 20; Bougainville I., Sta. 22.

Amphiroa fragilissima (L.) Lamx. Pulau Gaya area, Sta. 8; Duke of York Ids., Sta. 16.

Amphiroa tribulus (Sol.) Lamx.? Pulau Gaya area, Stas. 8, 9.

Jania tenella Kütz.? Bougainville I., Sta. 26. This small sample at first seemed to resemble *J. rubens,* but the upper branching was more spreading. The diameter of the lower axes ranged from 120-260 µm, which is not too different from *J. rubens,* but the segment length below was only 1.5-1.75 times the diameter and above to 2.0-2.5 times, which is too short for that species. In fact, it is rather short for *J. tenella* as figured by Kützing (1858, 8, pl. 85 II).

Grateloupiaceae

Halymenia durvillaei Bory. New Britain I., Stas. 21, 22; Guadacanal I., Sta. 27.

GELIDIALES

Gelidiaceae

Gelidiella acerosa (Forssk.) Hamel Pulau Gaya area, Stas. 8, 9; Bougainville I., Stas. 21, 25.

Gelidiella myrioclada (Børg.) Feldm. & Hamel Bougainville I., Sta. 25.

Gelidiopsis intricata (C. Agardh) Vick. Pulau Gaya area, Stas. 8, 10; Duke of York Ids., Sta. 16; New Britain I., Sta. 18; Bougainville I., Sta. 23.

Gelidiopsis repens (Kütz.) Schm. Bougainville I., Stas. 21, 25. The upper branching is more regularly digitate than figured by Okamura (1936, p. 636) but the resemblance to his figure is otherwise close.

Gelidium latifolium (Grev.) Thuret & Bornet, *prox*. Pulau Gaya area, Sta. 9; Bougainville I., Sta. 25.

Pterocladia caloglossoides (Howe) Dawson, *prox*. Bougainville I., Stas. 23, 25, 26. The fragments submitted are so small that the full habit cannot be confirmed, but in detail there is agreement.

GIGARTINALES

Hypneaceae

Hypnea cervicornis J. Agardh Pulau Gaya area, Stas. 10, 12; Duke of York Ids., Sta. 16.

Hypnea nidulans Setch.? Bougainville I., Sta. 23.

Hypnea spinella (C. Agardh) Kutz. Bougainville I., Sta. 23.

Sphaerococcaceae

Ceratodictyon spongiosum Zanard. Duke of York Ids., Sta. 16; New Britain I., Sta. 20.

Gracilariaceae

Gracilaria debilis (Forssk.) Børg. Mindanao I., Sta. 13.

Solieriaceae

Eucheuma crassum Zanard. Pulau Hantu, Sta. 1.

RHODYMENIALES

Champiaceae

Lomentaria hakodatensis Yendo ? Kieta area, Sta. 21. These plants are smaller and less branched than *L. sinensis* Howe (1924, p. 139, pl. 1 fig. 1), which has been reduced to synonymy under *L. hakodatensis,* and the tetrasporangial branchlets seem to stand erect and to be sagittate to lanceolate in shape. The lower branches often curve down and attach at the tips.

Champia parvula (C. Agardh) Harv. Pulau Gaya area, Stas. 6, 12; Mindanao I., Sta. 13; Duke of York Ids., Sta. 16; Bougainville I., Sta. 23.

Champia viellardii Kütz.? Bougainville I., Stas. 21, 23.

Coelarthrum boergesenii Weber-van Bosse. Bougainville I., Sta. 21.

CERAMIALES

Ceramiaceae

Antithamnion sp. Pulau Gaya area, Stas. 12, 12a. There was abundant material of this plant, but unfortunately it was all sterile. The plants were about 5 mm tall, growing on *Enhalus* leaves. The main filaments reached a diameter of 15-47 µm. The branchlets were opposite or verticillate, of equal length, sub-simple low on the axes, but above closely alternately branched, not secund. The cells near the bases of the branchlets were 12-14 µm diam., near the tips 7.7-9.3 µm. No gland cells were found.

Wrangelia bicuspidata Børg.? New Britain I., Sta. 15; Bougainville I., Sta. 21.

Griffithsia sp. Pulau Gaya area, Sta. 12. Not adequate for identification to species.

Ceramium sp. Duke of York Ids., Sta. 16. Same observation.

Centroceras clavulatum (C. Agardh) Mont. Pulau Gaya area, Sta. 12; Bougainville I., Sta. 26.

Spyridia filamentosa (Wulf.) Harv. Pulau Gaya area, Stas. 11, 12.

Delesseriaceae

Martensia flabelliformis Harv.? Pulau Hantu, Sta. 1.

Rhodomelaceae

Polysiphonia flaccidissima Hollenb., var. New Britain I., Sta. 19. Determined by the kindness of Dr. George F. Hollenberg.

Polysiphonia savatieri Hariot. Pulau Gaya area, Sta. 12. Determined by the kindness of Dr. George F. Hollenberg.

Tolypiocladia glomerulata (C. Agardh) Schmitz? Pulau Hantu, Sta. 1; Pulau Gaya area, Sta. 12; New Britain I., Sta. 15; Bougainville I., Sta. 23.

Bostrychia binderi Harv. Bougainville I., Sta. 25.

Bostrychia calliptera Mont.? Pulau Gaya area, Sta. 10.

Herposiphonia secunda (C. Agardh) Ambronn, *prox*. Bougainville I., Sta. 21.

Herposiphonia tenella (C. Agardh) Ambronn *prox*. Pulau Gaya area, Sta. 10; Bougainville I., Sta. 21.

Leveillea jungermannioides (Mart. & Her.) Harv. South China Sea, Sta. 4; Bougainville I., Sta. 24.

Amansia glomerata C. Agardh ? Bougainville I., Stas. 21, 23.

Acanthophora spicifera (Vahl) Børg. Pulau Hantu, Sta. 1; Pulau Gaya, Sta. 11; Bougainville I., Stas. 21, 22.

Laurencia obtusa (Huds.) Lamx. Pulau Gaya area, Sta. 12.

Laurencia papillosa (Forssk.) Grev. Pulau Gaya area, Stas. 6, 8; Duke of York Ids., Sta. 16; Bougainville I., Stas. 22, 23.

References

Chapman, V.J. 1971. The marine algae of Fiji. *Rev. Algol.*, n.s., 2(2): 164-171, pl. 17.

Dawson, E.Y. 1954. Marine plants in the vicinity of the Institut Océanographique de Nha Trang, Viet Nam. *Pacific Sci.* 8(4): 373-469, 63 text-figs.

Dawson, E.Y. 1956. Some marine algae of the southern Marshall Islands. *Pacific Sci.* 10(1): 25-66, 66 figs.

Dawson, E.Y. 1957. An annotated list of marine algae from Eniwetok Atoll, Marshall Islands. *Pacific Sci.* 11(1): 92-132, 31 text-figs.

Howe, M.A. 1924. Chinese marine algae. *Bull. Torrey Bot. Club* 51: 133-144, 2 pls.

Kutzing, F.T. 1858. *Tabulae Phycologicae.* 8: ii + 48 pp., 100 pl. Nordhausen.

Okamura, K. 1936. [*Marine algal flora of Japan.*] 11 + 964 + 11 pp., portr., 427 text-figs. Tokyo.

Setchell, W.A. 1924. American Samoa: Part I. Vegetation of Tutuila Island, pp. 1-188, 46 text-figs., pls. 1-20. Part III. Vegetation of Rose Atoll, pp. 225-261, figs. 47-57, pls. 32-37. *Carnegie Inst. Washington, Dept. Marine Biol.,* 20, *Publ.* 341.

Setchell, W.A. 1926. Tahitian Algae collected by W.A. Setchell, C.B. Setchell and H.E. Parks. *Univ. Calif. Publ. Bot.* 12(4): 61-143, pls. 7-22.

Setchell, W.A. 1935. Some marine plants of southeastern Melanesia. *Proc. Calif. Acad. Sci.,* iv, 21: 259-276, pls. 11-15.

Taylor, Wm. Randolph 1950. *Plants of Bikini and other Northern Marshall Islands.* xv + 227 + i pp., Frontisp. + 79 pl., Ann Arbor, Mich.

Taylor, Wm. Randolph 1973. Marine algae of the Smithsonian-Bredin Expedition to the Society and Tuamoto Islands. *Pacific Sci.* 27(1): 37-43, 11 text-figs.

Taylor, Wm. Randolph 1976. Notes on plants of the genus *Caulerpa* in the herbarium of Maxwell S. Doty at the University of Hawaii. *Atoll. Res. Bull.,* this issue.

Trono, G.C. jr. 1968. The marine benthic algae of the Caroline Islands, I. Introduction, Chlorophyta and Cyanophyta. *Micronesica* 4(2): 1-206, 19 pl.

Trono, G.C. jr. 1969. The marine benthic algae of the Caroline Islands, II. Phaeophyta and Rhodophyta. *Micronesica* 5(1): 25-119, 11 pl.

Trono, G.C. jr. 1972a. Notes on some marine benthic algae in the Philippines. *Kalikasan. Philip. Journ. Biol.* 1: 126-147, 21 figs.

Trono, G.C. jr. 1972b. The marine benthic algae of Siasi Island and vicinity, 1. Introduction and Chlorophyta. *Kalikasan. Philip. Journ. Biol.* 1: 207-228.

Trono, G.C. jr. 1973. Studies on the marine benthic Chlorophyta of Puerto Galera, Oriental Mindoro, Philippines. *Univ. Philip. Nat. Sci. Res. Council, Tech. Rep.* 1: 1-25, 24 figs.

Tsuda, R.T. & M.S. Belk 1972. Additional records of marine benthic algae from Yap, western Caroline Islands. *Atoll Res. Bull.* 156: 1-5.

Tsuda, R.T. 1966. Preliminary bibliography of the marine benthic algae in the central Pacific, Polynesia and Micronesia. *Hawaii Inst. Marine Biol., Techn. Rep.* 10: 1-13. (Mimeo. addendum, 3 pp., 1968).

Walker, E.H. 1947. Algae, pp. 348-352, *in* A Subject Index to Elmer D. Merrill's "A Botanical Bibliography of the Islands of the Pacific". *Contr. U.S. Nat. Herb.* 30(1): 323-402.

Weber-van Bosse, A. 1913-1923. Liste des algues du Siboga. I. Myxophyceae, Chlorophyceae, Phaeophyceae. *Siboga Expeditie....*, 59a: 1-186, figs. 1-52, pls. 1-5, 1913; *Id.*, II. Rhodophyceae i, *ibid.*, 59b: ii + 187-310, figs. 53-109, pls. 6-8, 1921; *Id.*, ii, *ibid.*, 59c: 311-392, figs. 110-142, pls. 9, 10, 1923. Leiden.

Womersley, H.B.S. & A. Bailey 1969. The marine algae of the Solomon Islands and their place in biotic reefs. *Philos. Trans. Roy. Soc., Lond.*, B, 255: 433-442.

Womersley, H.B.S. 1970. Marine algae of the Solomon Islands. *Philos. Trans. Roy. Soc., Lond.*, B, 259: 257-352, 10 text-figs., pl. 24-27.

Yamada, Y. 1926. The phyto-geographical relation between the Chlorophyceae of the Mariannes, Carolines and Marshall Islands and those of the Malay Archipelago, Australia and Japan. *Proc. Third Pan-Pacific Sci. Congr., Tokyo, pp. 964-966.*

ATOLL RESEARCH BULLETIN
NO. 210

MARINE ALGAE KNOWN FROM THE MALDIVE ISLANDS

by H. E. Hackett

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

CONTENTS

MARINE ALGAE KNOWN FROM THE MALDIVE ISLANDS

by H. E. Hackett [1]

Introduction

At the opening of the International Indian Ocean Expedition in 1964, 17 red algae, 5 green algae, and 2 brown algae were known from the Maldive Islands. These had been collected during the J. Stanley Gardiner Expedition (Barton 1903; Foslie 1903, 1907; Weber van Bosse and Foslie 1904) and the John Murray Expedition (Newton 1953). The coralline algae are in the Foslie Herbarium, others are in the British Museum.

During the Cambridge Expedition to Addu Atoll in the summer of 1964, Sigee (1966) collected algae from the southern part of the atoll and published ecological notes. Specimens were identified by Tsuda and Newhouse (1966). They added 7 bluegreens, 20 reds, 25 greens, and 7 browns to the list of known algae. Specimens are at the University of Hawaii. The Expedition reports (Stoddart 1966) provide extensive references on the natural features of the Maldives.

During the U. S. Navy Biological Expedition to the Chagos in August 1967, C. Rhyne collected at Addu. The species are reported in this paper, and vouchers are at the U. S. National Museum. As part of the International Indian Ocean Expedition, Cruise B of the R/V TE VEGA went to the Maldive Islands in 1964. Extensive algal collections were made at nine atolls.[2]

An area was usually sampled by removing algae from a square meter plot or by line transect. On occasion SCUBA, a two foot wire dredge or a six foot beam trawl were used. Some specimens were collected by other members of the scientific party.

The collections bring the total of known Maldive algae to 21 bluegreens, 163 reds, (about 30 additional entities from dredge hauls are too fragmentary for analysis), 83 greens, and 18 browns.

Hackett (1969b) compared the Maldive algae to those of the Marshall Islands, contrasted floristic differences between northern and southern atolls, and gave indicator genera for the Maldive ecosystem. Aregood

---

1 Present address: Little Diamond Island, Portland, Maine 04109
(Manuscript received November 1974 -- Eds.)

2 The field portion of this work was supported by the National Science Foundation U. S. Program in Biology.

and Hackett (1971) reported a new species of Dictyurus from the Maldives.

This paper reports habitat descriptions from Cruise B and a list of known Maldive algae. The list is based in part upon an unpublished PhD dissertation at Duke University (Hackett, 1969a). Specimens are at Duke University, Durham, N. C. and at the U. S. National Museum.

Maldive reef features

The Maldives form a double row of atolls on the Chagos-Laccadive Bank. They extend northward from the equator along the 73°E meridian for more than 600 miles, and include more than 2,000 islands. The islands are for the most part transient, building and eroding rapidly. Large populated islands have completely disappeared within the memory of living natives (Hasen Didi, 1964 personal communication). Probably because of this transient quality, the Maldivian language, Divehi, emphasizes reef types rather than islands. These terms are pertinent and should be accepted as part of contemporary atoll terminology.

Tracey, Cloud and Emery (1955) have standardized terms for atoll reef features. Their classification, while applicable to most Pacific atolls, is not adequate for many Maldive atolls. The Maldives have a more complex atoll structure than is typical in the Pacific. Most of the larger atolls are best described as atolls within atolls or composite atolls. In addition, because of the alternating monsoon wind pattern, the Maldives do not have typical windward and leeward sides. The terminology of Tracey, Cloud and Emery is followed where appropriate, but some new terms apply only to Maldive reef features.

Faru means a reef, part of which is above water at low tide. The faru may have an island, and it may be a part of the atoll rim or a formation in the lagoon.

Farus in the lagoon probably developed on cora-algal knolls. Such farus are frequently so well developed that each has a central lagoon and, thus, becomes a microatoll. A shallow lagoon of this type is called a falu. A deeper lagoon is called a velu (vilu), although the distinction between them is not always clear.[1]

Farus on the atoll rim may enclose a falu or velu. These are usually present when massive reef corals grow on the edge of the lagoon reef flat.

Atoll or atolu is the only Maldivian word placed into the English language. Yet, atolu in Divehi does not mean a circle of reef and islands enclosing a lagoon. Atolu refers only to a political division.

---

1 Spelling is based on recent interpretations from Divehi. These were prepared by N. T. Hasen Didi, during Cruise B. The Admiralty Chart name appears in parentheses after the corrected name.

The political unit usually corresponds to the English language concept of an atoll. However, the largest emergent atoll in the world is in the Maldives and is made up of two political units. The northern half is called Tiladummati Atoll and the southern half Miladummadulu Atoll.

Both Agassiz (1903) and Gardiner (1903) made extensive comments on the structure of Maldivian atolls, and Hass in 1962 proposed a new theory of atoll formation based on his expedition to the Maldives. Plates I and II show in cross section the conspicuous features of a typical Maldive atoll.

Environmental features

The only extensive records of air temperature are kept by the R. A. F. Meteorological Office at Gan, Addu Atoll. But some air and sea temperature records are available from expedition reports and Maldivian sources.

From the Addu records of 1959 to 1964 the lowest air temperature was a Jan. reading of 20.6°C, and the highest in April 32.8°C (Scorer, Mar. 1964 personal communication).

It is likely that surface water temperatures are similar throughout the year. Water temperatures of above 31°C were recorded in March and October from *Cymodocea* beds and lagoon reef flats. Lowest water temperatures are 27.2°C for lagoon surface readings in January. Agassiz (1903) showed that there is probably no appreciable temperature change from the top to the bottom of the lagoon.

Rainfall data from the northern islands are scant. Figures from the Maldive Ministry indicate that the northern islands have a rainfall that is nearly equal to that of Addu, which is the southern most atoll. But the rain of the northern monsoon atolls is seasonal with a peak during May at the beginning of the Southwest Monsoon. In contrast the continuously unsettled weather of Addu results in more even monthly rainfall.

The prevailing monsoon wind regulates the seasonally reversing currents. At least in the northern Maldives the cross bank currents move westward from December to April, during the Northeast Monsoon; and they move more or less eastward from May through August, during the Southwest Monsoon.

Tidal data are scant, but the U. S. Naval Oceanographic Office (1951) states that the mean high water interval for Malcolm or Mukundu Atoll in the northern Maldives is 10 hours, 20 minutes. Spring tide range is 2.7 feet. Mean tide range is 2.1 feet. Tidal streams are irregular and much variation occurs.

The best salinity records are those for Addu Atoll kept by Stoddart (1966).

Habitat descriptions

Algal ridge

The algal ridge, or windward atoll margin, is a sporadic feature in the Maldives. A supposed prerequisite for its development is a continuous onshore wind that provides the water agitation needed for massive coral growth. Where corals reach the surface a pavement of calcareous red algae develops in the surf.

Algal ridges are seen in the atolls of the eastern side of the archipelago on their eastern and northeastern rims and in the western atolls on their western and southwestern rims. These are the sites that face the open sea and the alternating monsoon winds.

The habitat was studied on Himmafuri Faru in the northeastern sector of Male Atoll. There were no surge channels and the pavement was of *Porolithon* and *Lithophyllum*. Crevices continuously flushed with water contained a richly developed algal turf, dominated by small creeping species of *Chondria, Laurencia, Hypnea,* and *Polysiphonia*. Occasional are *Amphiroa, Anadyomene, Caulerpa peltata, Dasya, Dictyosphaeria, Halimeda, Jania, Oscillatoria, Peyssonelia, Pocockiella, Rhipidiphyllon,* a tiny *Sargassum, Schizothrix, Valonia,* and *Valoniopsis*. *Heteroderma* is a common epiphyte.

Leeward atoll margin

Although there are no true leeward reef margins in the Maldives, comparable situations are common where the atoll rim does not face the open sea. The habitat was studied on the eastern side of North Malosmadulu, facing the interatoll flat. Surf is negligible and the reef corals do not reach the surface, but slope gradually to deep water. *Lithophyllum* dominates. Confined to crevices are turfs of *Chondria, Herposiphonia, Hypnea* and *Tolypiocladia*. Occasional are *Codium, Boodlea, Gelidium, Halimeda, Jania, Turbinaria,* and *Vidalia*. Epiphytes are *Acrochaetium, Enteromorpha,* and *Jania*.

Seaward reef flat

The seaward flat is usually behind an algal ridge. If there is no ridge the seaward reef flat slopes gradually into deep water and is probably not distinguishable from the leeward atoll margin in the Maldives. The community at Himmafuri Faru, behind the algal ridge, is in less than a meter of water, and in places very broad and flat with high water temperatures. The sponge symbioses, stinging corals, blue corals, and true corals are abundant. *Tridacna* is occasional.

Most of the algae are small and confined to crevices. Occasional are *Actinotrichia, Amphiroa, Caulerpa serrulata, Caulerpa racemosa, Dictyota, Goniolithon, Halimeda, Halymenia* (rare), *Jania, Padina, Peyssonelia, Pocockiella* and *Turbinaria*. Turf formers are *Boodlea, Chondria, Champia, Cladophora, Herposiphonia, Hypnea, Microdictyon, Polysiphonia,* and *Tolypiocladia*. *Acrochaetium, Erythrocladia,*

Fosliella, Heteroderma, Schizothrix, and *Sphacelaria* are epiphytic.

The turf algae are mostly infertile, partially developed, and of divergent growth forms. This habit is apparently due in great part to the feeding of various reef herbivores. In areas of greater protection, as interisland flats, occasional large clumps of *Ceramium* may develop. In areas of considerable water flow *Calothrix* turfs may be extensive.

Calcareous debris, beach rock, and pavements

Distinct zonation was observed only once. The supralittoral black zone of *Entophysalis* and some *Calothrix* develops where the calcareous debris is stable. Below this is a supralittoral lighter band of the same genera. Its origin is unknown. The upper limits of the littoral are marked by a heavy growth of *Entophysalis* and *Calothrix*. The color given to the substrate by these algae gradually decreases down to low tide. This would appear to be related to the thickness of the brown sheath of *Calothrix*. The sheath is not so thick on those trichomes from the lower littoral. In the sublittoral, most debris is covered with *Entophysalis* and penetrated by *Gomontia* and *Ostreobium* filaments.

Beach rock is usually covered with *Entophysalis,* which has considerable endolithic development. There are several other bluegreen and green endolithic filaments.

In the northern atolls shallow depressions in beach rock and littoral pavements near low tide may have minute algal turfs of *Boodlea, Calothrix, Ceramium, Cladophora, Dictyosphaeria, Erythrotrichia, Microcoleus, Oscillatoria, Polysiphonia, Schizothrix, Spirulina* and hydroids.

At Addu, beach rock has well developed turfs. Crevices contain *Anacystis, Caulerpa racemosa, C. serrulata, C. taxifolia, Ceramium, Centroceras, Chondria, Cladophora, Dictyurus, Ectocarpus, Enteromorpha, Hormothamnion, Jania, Microcoleus, Oscillatoria, Padina, Polysiphonia, Schizothrix, Sphacelaria,* and *Wrangelia.* Thick turfs entirely of *Calothrix* were collected on debris throughout the littoral and sub-littoral.

Mangrove

Rhizophora mucronata is occasional in protected sites along lagoon beaches. Where the prop roots of this mangrove extend into the sublittoral, an algal turf of *Gelidium, Jania,* and *Caulerpa racemosa* develops.

Cymodocea-Thalassia flat

Flats of *Cymodocea* and *Thalassia* are rare and turf development is usually sparse. They occur mostly on seaward reefs or adjacent to channels crossing the atoll rim, although small tufts of *Thalassia* may be in most any protected area. In the northern atolls, flats are composed of *Cymodocea rotundata* with some *Thalassia hemprichii.* The

latter is usually poorly developed and heavily epiphytized. The flat at Addu has *Thalassedondron ciliatum* in addition to *Cymodocea* and *Thalassia*.

Flats contain many algae that are not seen elsewhere. Near Himmafuri Village, Male Atoll, poorly developed specimens of *Acanthophora, Chondria, Gracilaria, Hypnea,* and *Leveillea* were collected along with a single *Acetabularia*. Dominant are large clumps of *Jania* and *Goniolithon*, the latter often overgrown with *Peyssonelia*. Occasional are *Boergesenia, Bryopsis, Caulerpa, Chaetomorpha, Champia, Cladophora, Dictyosphaeria, Halimeda, Padina, Sphacelaria,* and *Tolypiocladia*. *Acrochaetium, Entocladia, Entophysalis, Erythrotrichia, Fremyella, Hormothamnion, Microcoleus, Oscillatoria,* and *Schizothrix* are epiphytic on larger algae. *Thalassia* is commonly epiphytized by *Ceramium, Cladophora, Enteromorpha, Fosliella, Jania, Ulvella,* and many bluegreens.

The algal composition of the flat at Addu Atoll varied. In May the site had considerable silting with poor water visibility. Occasional are *Brachytrichia, Caulerpa, Centroceras, Ceramium, Champia, Chondria, Cladophora, Dictyosphaeria, Dictyota, Ectocarpus, Enteromorpha, Fosliella, Herposiphonia, Jania, Mastigocoleus, Microcoleus, Pocockiella, Turbinaria,* and *Udotea javensis*. Subsequent summer collections found *Boergesenia, Boodlea, Hydroclathrus, Rosenvingea, Spyridia, Tolypiocladia,* and *Udotea orientalis*.

Lagoon reef flat

In the northern atolls, if reef building corals occur on the lagoon periphery of the flat, masses of *Porolithon craspedium* and *P. gardineri* occur among them. In either case *Actinotrichia, Bryopsis, Cladophora, Dictyopteris, Gelidium, Goniolithon, Halimeda, Hypnea, Jania, Microdictyon, Peyssonelia, Pocockiella, Tydemania* (rare), *Valonia,* and *Vidalia* occur in crevices. *Acanthophora, Amphiroa, Boodlea, Caulerpa racemosa, C. serrulata, C. taxifolia, Centroceras, Champia, Cladophoropsis, Derbesia, Ectocarpus, Enteromorpha, Hypnea,* and *Sphacelaria* grow on the lower parts of corals. Epiphytes are *Acrochaetium, Asterocystis, Microcoleus, Schizothrix* and *Spirulina*.

At Addu Atoll both algal diversity and development is much greater. In crevices are *Acrochaetium, Amphiroa, Asterocytis, Boodlea, Botryocladia, Bryopsis, Caulerpa, Ceramium, Chaetomorpha, Champia, Chondria, Cladophora, Cladophoropsis, Codium, Derbesia, Dictyopteris, Dictyota, Dictyurus, Ectocarpus, Enteromorpha, Erythrotrichia, Galaxaura, Gelidium, Halimeda, Herposiphonia, Hypnea, Jania, Laurencia, Martensia, Microcoleus, Oscillatoria, Pocockiella, Polysiphonia, Schizothrix,* germinating *Sphacelaria* propagulae, *Spongomorpha, Struvea, Taenioma, Tolypiocladia,* and *Turbinaria*.

Velu

The only small lagoon or velu studied was on Himmafuri Faru. It is on the lagoon reef flat and separates the massive lagoon reef structure from the island. The velu has little water circulation and

the bottom at three to four meters is of bare calcareous sand with occasional clumps of *Acropora formosa*. Algae occurring as a turf on the lower parts of the coral are *Caulerpa, Dasya, Gelidiella, Herposiphonia, Jania,* and *Spyridia*.

Lagoon floor

The lagoon floor in northern atolls is rich in algae. Over 20% of all Maldive algal species were collected there only. Undoubtedly many were overlooked and several are too fragmentary for analysis. Dredge hauls were dominated by *Microdictyon* and *Pocockiella*. Other genera are *Anadyomene, Antithamnion, Botryocladia, Bryopsis, Callithamnion, Caulerpa, Ceramium, Chaetomorpha, Champia, Chondria, Chrysymenia, Dasya, Dictyopteris, Dictyota, Dictyurus, Enteromorpha, Entocladia, Entophysalis, Erythrotrichia, Fauchea, Gracilaria, Halimeda, Haloplegma, Heteroderma, Herposiphonia, Hypoglossum, Laurencia, Lophocladia, Martensia, Neomeris, Oscillatoria, Padina, Polysiphonia, Schizothrix, Sphacelaria, Spongomorpha, Struvea,* the flabellate form of *Tydemania, Udotea,* and *Valonia*.

Melobesioid algae were common only in a dredge haul in a channel crossing the atoll rim.

In contrast to northern atolls the lagoon floor at Addu Atoll seems to have a sparse algal community. *Caulerpa verticillata, Chaetomorpha, Cladophora, Heteroderma, Mastigocoleus, Schizothrix,* and *Udotea* occur.

Knoll reef flat and slope

Coral knolls are farus in the atoll lagoon. The three sites observed are Dunidu in Male Lagoon, Walla in South Nilandu Lagoon, and Madugali in Ari Lagoon. All have flats about 25 meters in width that slope away from emergent islands to a depth of 4 meters before dropping sharply to the lagoon floor. Dunidu is a disturbed site. The island is the British Administrative residence. Walla and Madugali are uninhabited.

Conspicuous at Dunidu is *Tydemania*. It is the only alga growing profusely above the surface of the corals. *Caulerpa, Chaetomorpha, Champia, Enteromorpha, Halimeda, Herposiphonia, Hypnea, Struvea,* and *Tolypiocladia* are in crevices. Most dead corals were covered with mixtures of *Entophysalis, Hormothamnion, Microcoleus, Schizothrix,* and the arcuate tufts of *Oscillatoria*.

At Walla coral crevices contained *Acrochaetium, Amphiroa, Caulerpa, Ceramium, Chlorodesmis, Cladophora, Coelarthrum, Codium, Derbesia, Dictyurus, Dictyota, Asparagopsis* (tetraspotophytes), *Griffithsia, Halimeda, Herposiphonia, Heteroderma, Hormothamnion, Hypoglossum, Pocockiella, Porphyrosiphon, Schizothrix, Sphacelaria, Spirulina, Struvea, Turbinaria, Udotea,* and *Vidalia*.

At Madugali *Halimeda* is dominant but confined to crevices along with *Acrochaetium, Caulerpa racemosa, Ceramium, Chondria, Hypoglossum,*

231-339 O - 77 - 4

Jania, and *Wrangelia.*

The rubble pool at Filadu, Tiladummati Atoll

Near a channel crossing the reef flat, a circular mass of calcareous debris enclosed a pool about 20 meters in diameter and a meter in depth. The wall, which served as a tern rookery, allowed algae to grow free from wave activity and grazing by herbivorous fishes.

Although large clumps of *Halimeda* occurred, the pool was dominated by entangled and partially free floating mats of the Cnidarian *Zoanthus* mixed with *Caulerpa racemosa* var. *microphysa* and *C. sertularioides.* The *Caulerpa* was the most profusely developed of any shallow water alga in the Maldives.

Stations of Cruise B of the R.V. *Te Vega* 1964

Male Atoll

2. Mar. 17. Dunidu Faru. (73°30'15"E, 4°11'30"N). Littoral beach rock and smooth calcareous pavement on the east side of the coral knoll island.

3. As above. Reef flat, reef margin, reef front, 1-2 meters of water on the north side.

4. Mar. 19. Himmafuri Faru. (73°34'E, 4°18'30"N). *Cymodocea* bed just below low tide on the north side of the island near the village.

5. Mar. 21. As above but on the south side of the island.
5a. Seaward reef flat, 1 meter or less of water.
5b. Algal ridge.
5c. Velu, 3-4 meters of water.

6. Mar. 22. South of Kagi Faru. (73°34'E, 4°32-35'N). Lagoon floor in 60-66 meters, beam trawl.

7. Mar. 22. Kagi Faru. (73°29'45"E, 4°40'N). Seaward reef flat on the north side of the Faru, 2-6 meters of water.

Fadiffolu Atoll

8. Mar. 23. Between Mako (Maro) and Mafilafuri (Mafilefuri). (73°25'24"E, 5°21'30"N). Inter-island flat of calcareous debris, less than 1 meter of water with current.

9. Mar 24. As above but nearer the lagoon side, sheltered water at the point of low tide.
9a. *Rhizophora* roots.
9b. Coral debris especially *Acropora.*
9c. Sparse *Thalassia* bed.

10. Mar. 25. East of Lohi and Lasalafuri. (73°29'E, 5°20'N). Lagoon floor in 50-70 meters, beam trawl.

11. Mar. 25. Near Maduvvari. (73°29'E, 5°18'N). Channel across the atoll reef in 50-70 meters, beam trawl.

Miladummadulu Atoll

12. Mar. 27. Kendikolu. (73°2'E, 5°57'N). Lagoon reef flat, 3 meters of water.

13. Mar. 27. Just west of Kendikolu. Lagoon floor in 50 meters, wire dredge.

14. Mar. 28. Kendikolu. Patch reef adjacent to the lagoon beach, less than 1 meter of water.

15. Mar. 29. Near Bomasdu. (73°19'E, 5°58'N). Lagoon floor in 72 meters, beam trawl.

Tiladummati Atoll

16. Mar. 31. Filadu. (73°10'E, 6°55'N). Enclosed rubble pool on the reef flat.

17. As above. Lagoon reef flat outside the pool, 5 meters of water.

Male Atoll

18. Apr. 19. Dunidu Faru. See station 2. Littoral pools on pavement and the pavement at the point of low tide.

19. Apr. 19. As station 3.

North Malosmadulu Atoll

20. Apr. 21. Ugu Faru (Ongu). (73°0'E, 4°40'N). Site similar to a leeward reef flat, 1-3 meters of water.

21. Apr. 21. Near Ugu Faru. (73°0'E, 4°41'N). Lagoon floor in 44 meters, wire dredge.

Ari Atoll

22. Apr. 22. Madugali. (72°45'E, 4°6'N). Beach rock and the reef flat of a coral knoll island, to 2 meters of water.

South Nilandu Atoll

23. Apr. 23. Kuda Huvadu. (72°55'E, 2°42'N). Floating algal mat from the lagoon beach.

24. Apr. 24. Walla Faru (Wala). (72°55'E, 2°42'N). Reef flat of a coral knoll island.

<u>Addu Atoll</u>

25. Apr. 28. Gan Island. (73°9'E, 0°41'S). Littoral beach rock from the lagoon beach near the inter-island flat.

26. Apr. 30. Wilingili. (73°11'E, 0°41'S). Lagoon reef flat, less than 1 meter of water.

27. May 4. As station 25. Coral rubble surrounding the pier on the lagoon beach, 1 meter of water.

28. May 5. North of the Gan-Fedu gap. (73°9'E, 0°41'S). Lagoon floor in 40-50 meters, wire dredge.

29. May 8. As station 25. Small rubble island on the inter-island flat between Gan and Fedu. *Cymodocea-Thalassia* beds and littoral calcareous debris.

30. May 10. Busby Island. (73°10'E, 0°40'S). Lagoon reef flat on the western side of the island, coral rubble and shells in 1 meter of water.

Stations of other expeditions

<u>Barton</u>. Algae collected during the J. Stanley Gardiner Expedition to the Maldives were listed by Barton (1903). All the Maldive plants were dredged in water 25-45 fathoms. The locations are given in the systematic list.

<u>Foslie</u>. Coralline algae collected during the Gardiner Expedition were listed by Foslie (1903, 1907) and Weber Van Bosse and Foslie (1904). The locations are given in the systematic list.

<u>DS</u>. Algae collected by D. Sigee during the Cambridge to Addu Atoll were listed by Tsuda and Newhouse (1966). For locations consult that paper.

<u>Rhyne</u>. Algae were collected at Addu Atoll in August 1967 by C. Rhyne during the U.S. Navy Biological Expedition to Diego Garcia. All were found on the shallow inter-island flat between Gan and Fedu.

Systematic list

Cyanophyceae

Anacystis aeruginosa (Zanardini) Drouet and Daily
Stations: 23, 25; on *Enteromorpha* and *Schizothrix* or interstitial.

Brachytrichia maculans Gomont
Stations: 29; on calcareous debris with *Calothrix* in *Cymodocea* beds.

Calothrix crustacea Schousboe and Thuret
Stations: 4, 18, 22, 29; on coral debris, beach rock and on *Cymodocea*.

Calothrix pilosa Harvey
Stations: 8, 16, 29: DS 120: forming a turf on coral rubble in *Cymodocea* beds or blackening supralittoral debris in undisturbed areas.

Coccochloris elabens (Brebisson) Drouet and Daily
Stations: 15; Several irregular and often medianly constricted cells of this tentatively identified alga (Drouet, 1967 personal communication) are within many of the blade cells of the monostramatic specimens of *Dictyopteris*.

Entophysalis conferta Drouet and Daily
Stations: 3, 5a, 5b, 5c, 15, 18; on *Microcoleus, Schizothrix, Polysiphonia,* and *Valoniopsis*.

Entophysalis deusta Drouet and Daily
Stations: 3, 4, 8, 9, 13, 16, 18, 26; on and in calcareous debris.

Fremyella vitiensis (Askenasy) De Toni
Stations: 4, on various algae in *Cymodocea* beds.

Hormothamnion enteromorphoides Grünow
Stations: 4, 25; on *Bøergesenia, Thalassia,* and *Cymodocea* or forming a crust on sand in crevices of beach rock.

Hormothamnion solutum Bornet and Grünow
Stations: 9; Rhyne 814a; in the algal turfs on *Rhizophora* roots and on *Thalassia*.

Mastigocoleus testarum Lagerheim
Stations: 9, 28, 29; penetrating beach rock and shell debris.

Microcoleus lyngbyaceus (Kützing) Crouan
Stations: 3, 4, 5a, 5b, 5c, 9, 16, 17, 18, 25, 26, 29, 30; Rhyne 816b; on coral debris, beach rock, in sand or epiphytic, never dredged.

Oscillatoria submembranacea Ardissone and Strafforello
Stations: 3, 4, 5a, 5c, 9, 10a, 16, 17, 25, 30; Rhyne 825; forming erect tufts on beach rock or coral debris, or forming spheres, binding sand, or epiphytic.

Oscillatoria lutea Agardh
Stations: 4, 26; on calcareous debris in *Cymodocea* beds.

Porphyrosiphon notarisii (Meneghini) Gomont
Stations: 15, 24; on a hydroid, on *Microdictyon*.

Rivularia polyotis (J. Agardh) Bornet and Flahault
Stations: 9, on *Thalassia*, on shells.

Schizothrix arenaria (Berkeley) Gomont
Stations: 5a, 5c, 10a, 25; Rhyne 815; in sand.

Schizothrix calcicola (Agardh) Goment
Stations: 3, 4, 5, 8, 9, 16, 17, 18, 21, 25, 26, 28; DS88; a common algal epiphyte and often in the tissues of sponges and *Zoanthus*.

Schizothrix mexicana Gomont
Stations: 5a, 5b, 5c, 9, 10a, 11b, 15, 17, 20, 24, 26, 28; Rhyne 816a; with other bluegreen algae in turfs especially on the lower parts of coral, or epiphytic on red algae.

Schizothrix tenerrima (Gomont) Drouet
Stations: 20, on *Gelidium*.

Spirulina subsalsa Oersted
Stations: 9, 16, 17, 18, 20; in turfs with other bluegreen algae especially *Microcoleus*.

Rhodophyceae

Acanthophora spicifera (Vahl) Børgesen
Stations: 4, 9b; in *Cymodocea* and *Thalassia* beds, rare. Plants of small stature and heavily epiphytized.

Acrochaetium sargassicola Børgesen
Stations: 20, 30; on *Dictyota, Turbinaria,* and coralline algae.

Acrochaetium sp. 1
Stations: 17, 22, 26, 30; on various algae. Plants resemble *A. gracile* Børgesen, but with larger dimensions.

Acrochaetium sp. 2
Stations: 4, 24; on *Champia* and *Hypnea* from *Cymodocea* beds, on *Dictyota* from the reef flat. Plants 0.2mm - 0.4mm high, sparsely branched; basal cell 18 μ diam., spherical, at least in young plants, ultimately forming a filamentous creeping axis or a disk like

structure; lower cells of the upright axis 7-8 μ diam., 10 μ long, ultimate unicellular branchlets usually arising from each of the 2-4 cells of a side branch; plastid band shaped to fragmented.

Actinotrichia fragilis (Forskal) Børgesen
Stations: 7, 17; occasional in crevices.

Amphiroa anastomosans Weber Van Bosse
Stations: 5b, 7, 24, 26; in crevices of the reef flat and in mixed algal turfs of the algal ridge.

Amphiroa fragilissima Lamouroux
Stations: 5b, 9b; in algal turfs.

Amphisbetema indica (J. Agardh) Weber Van Bosse
Stations: DS 112.

Antithamnion breviramosus Dawson
Stations: 7, 10a; on *Valonia* from the reef flat, on dredged *Halimeda*. The axis diameter is smaller than variety *simplex* Dawson (1957) from Eniwetok. Plants are poorly developed, and not all have gland cells.

Antithamnion butleriae Collins
Stations: 10a. Species previously known only from the West Indies.

Antithamnion pseudocorticatum Dawson
Stations: 15, on *Microdictyon*. Plants are better developed than the type. The lower side of the basal cell of the ramuli cuts off a spherical but not densely staining gland-like cell.

Antithamnion sp. 1
Stations: 15, on *Microdictyon* and *Dictyopteris*. Plants are like *A. sublittorale* Setchell and Gardiner, but have di-trizonate gland cells.

Antithamnion sp. 2
Stations: 10a, on calcareous debris. Plants fragmentary, indeterminate axes unbranched, cells 15 μ diam., 50 μ long; determinate ramuli arising near the upper end of the axis cell, opposite, unbranched, to 175 μ long, lower cells 10 μ diam., 17 μ long, terminal cell 5 μ diam., 12 μ long, blunt; flattened gland cells 10 μ long, laterally cut off from lower cells of the ramuli.

Antithamnion sp. 3
Stations: 15, on *Microdictyon*. Plants fragmentary, axis cells 20 μ diam., 70 μ long, each giving rise in a spiral arrangement to two adjacent and thus not opposite, unbranched, determinate ramuli to 180 μ long, one often deciduous in older parts; cells of lower ramuli 8 μ diam., 20 μ long, terminal cell blunt; supposed gland cells not as distinctively dark at maturity as most species, ovoid to spherical 10 μ – 15 μ borne usually on the lower side at a midpoint on the ramuli.

Archaeolithothamnion erythraeum (Rothpletz) Foslie
Stations: Foslie, South Nilandu.

Archaeolithothamnion schmidtii Foslie f. *dissita* Foslie
Stations: Foslie, South Nilandu and Male

Asparagopsis taxiformis (Delile) Collins and Hervey
Stations: 24, 26; tetrasporophytic plants only.

Asterocytis ornata (C. Agardh) Hamel
Stations: 12, 17, 24, 26, 30; on *Sphacelaria, Entophysalis, Polysiphonia* and other turf algae in crevices.

Botryocladia skottsbergii (Børgesen) Levring
Stations: 15, 21, 26; DS 23.

Callithamnion sp.
Stations: 10a, 15: Plants erect to 1cm, axes monosiphonous, alternate to dichotomously branched, branches spirally arranged and apparently indeterminate and not differing from the axes, usually straight; lower cells 37-55-75 μ diam., 212-250 μ long, somewhat expanded at the ends; upper cells 15 μ diam., 100 μ long; terminal cells 8 μ diam., 26 μ long, apex wall very thick, blunt; not reproductive.

Centroceras clavulatum Montagne
Stations: 9b, fragments numerous in algal turfs on dead coral.

Centroceras minutum Yamada
Stations: 9b, 26, 29; in algal turfs on dead coral.

Ceramium fibriatum Setchell and Gardner
Stations: 8, DS 105; on sandy areas of the reef flat, rare. These plants are the only conspicuous *Ceramium* species found.

Ceramium gracillimum (Griffiths) Harvey var. *byssoideum* (Harvey) Mazoyer
Stations: 4, 7, 22, 24, 29; Rhyne 804, on *Cymodocea, Thalassia, Halimeda, Dictyota,* and *Amphiroa*.

Ceramium mazatlanense Dawson
Stations: 10, 11, 21, 24; on *Codium* and *Dictyota* from the reef flat and on *Bryozoans, Microdictyon,* and *Pocockiella* from the lagoon floor. Plants are less developed than typical.

Ceramium sp. 1
Stations: 25, 30; on beach rock and debris. Plants have a greater number of tetrasporangia at a node and a more regular arrangement of cortical cells than *C. huysmansii* Weber Van Bosse.

Ceramium sp. 2
Stations: 9c, on *Thalassia*. Plants to 3mm high, sparingly and irregularly branched, apices curved; mature axis cells 85 μ diam.,

150 μ long; mature cortical band 200 μ diam., 100 μ high with some secondary growth, cells 8-24 μ diam., irregular not organized into zones; forming bisporangia, 27 μ diam., 46 μ long, up to 10 at a node, involucrate.

Ceramium sp. 3
Stations: 18, on beach rock. Plants to 2mm high, sparingly and irregularly branched, apices straight, mature axis cells 125 μ diam., 187 μ long; mature cortical band 150 μ diam., 125 μ high with much secondary growth, cells usually round 13 μ, not organized into zones, not reproductive.

Ceramium sp. 4
Stations: 30, on coral debris. Plants creeping to erect, minute, rarely branched, apices straight; mature axis cells 33 μ diam., 90 μ long; mature cortical bands 43 μ diam., 24 μ high; cells irregular 8-13 μ, irregularly arranged into more or less three transverse zones, rhizoids occasional arising from the bands, not reproductive.

Ceramium sp. 5
Stations: 15, on *Microdictyon*. Plants to 3mm high, abundant dichotomous to alternate branching, apices straight; mature axis cells 163 μ wide 188 μ long, bulging; mature cortical bands 160 μ wide, 62 μ high; cells small highly irregular with some gland cells, not reproductive.

Ceratodictyon spongiosum Zanardini
Stations: DS 69.

Champia parvula (C. Agardh) Harvey
Stations: 3, 4, 7, 9b, 9c, 26, 29; DS 122a; Rhyne 810; on *Thalassia, Gelidium, Dictyosphaeria, Padina* and other algae.

Champia salicornoides Harvey
Stations: 21; DS 122b.

Champia sp.
Stations: 13; Plant fragmentary to 3cm high; .5-1mm diam., sparingly branched; not constricted at septa; wall of one layer, cells 34-84 μ long, 28 μ diam., small cells interspersed 10 μ diam., medullary filaments 5 μ diam.

Chondria dasyphylla (Woodward) C. Agardh
Stations: 4, rare. Plants are poorly developed.

Chondria simplicuscular Weber Van Bosse
Stations: 4, 5b, 5c, 7, 20, 25; a common component of turfs.

Chondria spp.
Four additional species of *Chondria* from the reef flat and lagoon floor are being studied.

Chrysymenia sp.
Stations: 11. Plants fragmentary but resemble *C. enteromorpha* Harvey but have cells twice the size.

Coelarthrum boergesenii Weber Van Bosse
Stations: 24, rare, in crevices. Gland cells are not distinctive or numerous.

Crouania minutissima Yamada
Stations: 11.

Cruoriella sp.
Stations: 4, 20; on calcareous debris from the reef flat and on *Conus* from a *Cymodocea* bed.

Cryptonemia crenulata J. Agardh
Stations: 15. Surface cells are slightly smaller than typical West Indian plants.

Dasya spp.
Three species of *Dasya* from the lagoon floor and algal ridge are being studied.

Dasyopsis geppii Weber Van Bosse
Stations: DS 95,101.

Dictyurus maldivensis Hackett and Aregood
Stations: 13, 15; see Aregood and Hackett (1971).

Dictyurus purpurascens Bory in Belanger and Bory.
Stations: 24, 25, 26; DS 24.

Erythrocladia subintegra Rosenvinge
Stations: 7, 26; on *Valonia* and *Struvea* from crevices.

Erythrotrichia carnea (Dillwyn) J. Agardh
Stations: 4, 10, 25, 26, 30; on *Champia, Hypnea, Dictyota* and *Thalassia* from the reef flat, on *Pocockiella* from the lagoon floor.

Fauchea peltata Taylor
Stations: 6; DS 64.

Fauchea repens (C. Agardh) Montagne
Stations: 15.

Fosliella farinosa (Lamouroux) Howe
Stations: 4, 7, 9c, 26, 29; on *Cymodocea, Thalassia,* and various algae.

Fosliella sp. 1
Stations: 4, on *Padina* and *Dictyosphaeria*. Plants mostly three cell layers thick; cells 15 μ diam., 20 μ long, cap cells lacking; heterocysts 25-32 μ diam., 32-37 μ long, colorless, spherical to ovoid.

Fosliella sp. 2
Stations: 4, 12; on *Cymodocea* and *Valonia*. Plants mostly one cell layer thick; cells variable 10 μ diam., 15 μ long, cutting off cap cells that are prominent on the surfaces of immature conceptacles; heterocysts 12 μ diam., 26 μ long, not particularly distinctive.

Galaxaura filamentosa Chou
Stations: 26, on calcareous debris.

Galaxaura marginata (Ellis and Solander) Lamouroux
Stations: DS 104.

Galaxaura rudis Kjellman
Stations: DS 21.

Gelidiopsis sp.
Stations: 10. Plants fragmentary.

Gelidium crinale (Turner) Lamouroux
Stations: 9a, on roots of *Rhizophora mucronata*.

Gelidium divaricatum Martens
Stations: 20, 26; DS 72; in algal turfs.

Galidium pusillum (Stackhouse) Le Jolis var. *miniscula* Weber Van Bosse
Stations: 26.

Gelidiella sp.
Stations: 5c, 26, in algal turfs on *Acropora*.

Gracilaria corticata J. Agardh
Stations: 4, rare. Plants poorly developed.

Gracilaria sp.
Stations: 4, rare. Plants are poorly developed but resemble *G. verrucosa*. Central cells are smaller than typical and branches do not show the basal attenuation of Ceylon specimens.

Griffithsia rhizophora (Grünow) ex Weber Van Bosse
Stations: 24; DS 80; in algal turfs on *Dictyota, Caulerpa,* and *Hypnea*.

Griffithsia tenuis C. Agardh
Stations: 24, on *Halimeda*.

Goniolithon fosliei (Heydrich) Foslie
Stations: Foslie, Male.

Goniolithon frutescens Foslie
Stations: 4, 5a, 9b; DS 98, 113; Rhyne 798c, 828; Foslie, Male and Suvadiva.

Goniolithon frutescens Foslie f. *congesta* Foslie
Stations: 9b; Rhyne 820a; Foslie, Male and Suvadiva.

Goniolithon laccadivicum Foslie f. *typica* Foslie
Stations: Foslie, Male.

Goniolithon myriocarpon Foslie
Stations: Foslie, Male.

Goniolithon reinboldi (Weber Van Bosse and Foslie) Foslie
Stations: Foslie, Male.

Goniolithon sp.
Stations: 4, on *Goniolithon frutescens*.

Haloplegma duperrayi Montagne
Stations: 15.

Halymenia durvillaei Bory
Stations: 5a, 5d, 7; DS 121. Plants poorly developed and very rare.

Herposiphonia crassa Hollenberg ?
Stations: 9b, on Dictyota from coral rubble.

Herposiphonia delicatula Hollenberg
Stations: 9b, 21.

Herposiphonia dendroidea Hollenberg var. *minor* Hollenberg
Stations: 30.

Herposiphonia filifera Hollenberg
Stations: 15, 26.

Herposiphonia obscura Hollenberg
Stations: 11.

Herposiphonia pacifica Hollenberg
Stations: 5a, 5c, 9b, 20, 29; on Caulerpa and other algae.

Herposiphonia parca Setchell
Stations: 5c, 7, 24, 29; DS 78; in *Cymodocea* beds and on *Acropora*.

Herposiphonia tenella (C. Agardh) Schmitz
Stations: 24, on *Pocockiella*.

Herposiphonia tenella (C. Agardh) Schmitz f. *secunda* (C. Agardh) Hollenberg
Stations: 24.

Heteroderma lejolisii (Rosanoff) Foslie
Stations: 5b, 7, 21, 24, 26, 28; on *Valonia, Chaetomorpha, Struvea, Valoniopsis, Chondria, Microcoleus* and other algae.

Heteroderma sp. 1
Stations: 5b, 7; on *Hypnea, Pocockiella* and *Valonia*. Plants one cell layer, initial branhcing dichotomous, cells rectangular; ultimate branching irregular but parallel, cells sigmoid 10 μ diam., 22 μ long. Adjacent branches form a reticulate pattern the lense shaped openings are formed by two sigmoid cells; cap cells but no heterocysts.

Heteroderma sp. 2
Stations: 5b, on *Chondria*. Plants one cell layer, in crusts to 125 μ wide, cells 7-12 μ diam., 10-17 μ long; crusts connected by irregularly branched filaments, cells 12 μ diam., 25-32 μ long; cap cells but no heterocysts.

Heteroderma sp. 3
Stations: 5b, 12; on *Valonia* and *Laurencia*. Plants one cell layer, mostly of fan-like reticulate crusts formed by dichotomous branching some plants with a more filamentous tendency, cells irregular 8-10 μ diam., 10-25 μ long; conceptacles 85 μ high, 50 μ basal diam., conical tapering to a single pore; cap cells but no heterocysts.

Heterosiphonia sp.
Stations: 13, 15. Plants with distinctive acute apices.

Hypnea esperi Bory
Stations: 3, 4, 5b, 7, 9c, 16, 20, 24, 26; DS 12, 18, 93; Rhyne 826.

Hypnea valentiae (Turner) Montagne
Stations: 4, 9b; DS 91; Rhyne 807.

Hypoglossum minimum Yamada
Stations: 10, 13, 22, 24.

Hypoglossum sp.
Stations: 28, on a tunicate. A single small spermantangial plant.

Jania capillacea Harvey
Stations: 4, 5b, 5c, 7, 9a, 9b, 10, 11, 17, 20, 22, 23, 25, 26, 29, 30; DS 11; Rhyne 809a. Plants are almost always a component of algal turfs, but best developed in *Cymodocea* beds. Two dredged fragments were probably washed from the reef.

Janua ungulata Yendo
Stations: 20, on *Turbinaria*.

Laurencia parvipapillata Tseng
Stations: 5b.

Laurencia spp.
Six additional species of *Laurencia* from the lagoon floor are being studied.

Leveillea jungermannioides (Martens and Hering) Harvey
Stations: 4, rare.

Lithophyllum kotschyanum Unger f. *typica* Foslie
Stations: 5b, 12; DS 92; Foslie, Male.

Lithophyllum kotschyanum Unger f. *madagascarensis* Foslie
Stations: Foslie, Male.

Lithophyllum kotschyanum Unger f. *subplicata* Foslie
Stations: Foslie, Male.

Lithophyllum kaiserii Heydrich f. *subplicata* Foslie
Stations: Foslie, Male.

Lithophyllum spp.
Three additional species of *Lithophyllum* are being studied.

Lithothamnion maldivicum Foslie
Stations: Foslie, Male.

Lithothamnion indicum Foslie f. *typica* Foslie
Stations: Foslie, Male, Addu and South Nilandu.

Lithothamnion fructiculosum (Kützing) Foslie f. *clavulata* Foslie
Stations: Foslie, Male and South Nilandu.

Lithothamnion spp.
Two additional species of *Lithothamnion* including DS 117 are being studied.

Lithoporella melobesioides (Foslie) Foslie
Stations: 4; Foslie, South Nilandu.

Lophocladia lallemandii (Montagne) Schmitz
Stations: 15.

Martensia fragilis Harvey
Stations: 10, 26.

Peyssonelia calcea Heydrich
Stations: 3, on *Acropora*.

Peyssonelia gunniana J. Agardh
Stations: DS 53.

Peyssonelia rubra (Greville) J. Agardh var. *orientalis* Weber Van Bosse
Stations: 12; Barton, Suvadiva.

Peyssonelia spp.
Five additional species of *Peyssonelia* from the reef flat are being studied.

Polysiphonia exilis Harvey
Stations: 24, with *Herposiphonia* on corals.

Polysiphonia ferulacea Suhringer in J. Agardh
Stations: DS 35a.

Polysiphonia flaccidissima Hollenberg
Stations: 21, 30.

Polysiphonia howei Hollenberg
Stations: 18.

Polysiphonia pentamera Hollenberg
Stations: 13.

Polysiphonia poko Hollenberg var. *langii* Hollenberg
Stations: DS 35.

Polysiphonia scopulorum Harvey var. *villum* J. Agardh
Stations: 7; DS 29, 98.

Polysiphonia spherocarpa Børgesen
Stations: 26.

Polysiphonia tepida Hollenberg
Stations: 21.

Polysiphonia upolensis (Grunow) Hollenberg
Stations: 30; DS 29c.

Porolithon craspedium (Foslie) Foslie f. *typica* Foslie
Stations: 12; Foslie, Male.

Porolithon craspedium (Foslie) Foslie f. *compressa* Foslie
Stations: Foslie, Male.

Porolithon craspedium (Foslie) Foslie f. *abbreviata* Foslie
Stations: 5b; Foslie, Male.

Porolithon gardineri (Foslie) Foslie f. *typica* Foslie
Stations: 12.

Porolithon onkodes (Heydrich) Foslie
Stations: 5b, 9b; DS 116: Foslie, Male.

Porolithon sp.
Stations: 5b, the prime constituent of the algal ridge. Plants are like *P. craspedium* in part, but are much encrusted and perforated and may be *P. gardineri* or *P. sequinoctale*.

Spermothamnion?
Stations: 5c, 6. Plants not reproductive.

Spyridia filamentosa (Wulfen) Harvey in Hooker
Stations: 5c; DS 97: Rhyne 808a.

Taenioma nanum (Kützing) Papenfuss
Stations: 26 in an algal turf on *Acropora*.

Tolypiocladia glomerulata (C. Agardh) Schmitz
Stations: 3, 4, 7, 20, 26, 30; DS 44; Rhyne 801, 819.

Wrangelia argus Montagne
Stations: 22, 25.

Vidalia serrata (Suhringer) J. Agardh
Stations: 26; DS 19.

Vidalia sp.
Stations: 16, 17, 20, 24; in crevices. Plants erect to 4cm, bushy and compact, axes flat to 1mm broad; cross section .3mm thick near margin, .37mm thick in center; alternately branched and ultimately spinulose; upper apices inrolled; faintly costate on staining; axis cells 100-200 μ long, 75-90 μ diam., pericentrals 5; two layers of cortical cells, outer 5 μ diam., 10 μ long usually in pairs; inner cells 100-125 μ long ovoid; gland cells ovoid 12 μ diam., 22 μ long often reaching the surface; spermatangial clusters near the apices.

Chlorophyceae

Acetabularia sp.
Stations: 4. A single immature specimen.

Anadyomene wrightii Gray
Stations: 5b, 10, on *Valoniopsis* in the algal ridge and lightly attached to sand on the lagoon floor.

Bøergesenia forbesii (Harvey) Feldmann
Stations: 4, 30; DS 6; Rhyne 831.

Boodlea composita (Harvey) Brand
Stations: 5c, 18, 26; DS 94; Rhyne 799. Plants from northern atolls are smaller in all aspects than what is usually reported and resemble *B. struveoides* Howe. Addu plants are typical.

Boodlea van-bosseae Reinbold
Stations: 9b, 20, 30, on rubble or in algal turfs.

Boodlea sp.
Stations: DS 63. Plants minute, inner cells 22 μ diam., 58-72 μ long; ultimate cells 22 μ diam., 31 μ long, often curved, some smaller and rhizoidal; hapteral cells various but usually square 22 μ.

Bryopsis pennata Lamouroux
Stations: 26; DS 14, 54.

Bryopsis sp.
Stations: 21, on *Struvea*. Axis .25mm basal diam., .2mm diam. where ramuli diverge; ramuli alternate, 62 μ diam., 1.5mm long, basally constricted to 25 μ, obtuse, mature ramuli often septate at base or with ingrowths of the wall; plastids oval to spindle shaped connected by fine strands.

Caulerpa ambigua Okamura
Stations: 4, 19, 26, 30.

Caulerpa crassifolia (C. Agardh) J. Agardh
Stations: 13, 10, 11, 24.

Caulerpa lentillifera J. Agardh
Stations: DS 8b.

Caulerpa racemosa (Forskål) J. Agardh var. *clavifera* (Turner) Weber Van Bosse f. *simplicissima* Børgesen
Stations: 9c; Rhyne 802a.

Caulerpa racemosa (Forskål) J. Agardh var. *macrophysa* (Kützing) Taylor
Stations: 7, 8, 9b, 22, 25, 26; DS 8a; Rhyne 811.

Caulerpa racemosa (Forskål) J. Agardh var. *microphysa* (Weber Van Bosse) Taylor
Stations: 16.

Caulerpa racemosa (Forskål) J. Agardh var. *peltata* (Lamouroux) Eubank
Stations: 5b, 5c, 24, 26, 30; Rhyne 802(2).

Caulerpa serrulata(Forskål) J. Agardh var. *typica* (Weber Van Bosse) Tseng
Stations: 8, 9b, 25, 30; DS 47; Rhyne 802(1), 812.

Caulerpa sertularioides (Gmelin) Howe
Stations: 16, 17.

Caulerpa taxifolia (Vahl) C. Agardh
Stations: 9c, 9b, 25; DS 10; Rhyne 803.

Caulerpa verticillata J. Agardh
Stations: 28.

Caulerpa sp.
Stations: 21. Plants as *C. serrulata* but with reduced serrations and no twisting.

Chaetomorpha brachygona Harvey
Stations: DS 66.

231-339 O - '77 - 5

Chaetomorpha crassa (C. Agardh) Kützing
Stations: 4, 11, 15; DS 106; Rhyne 824.

Chaetomorpha gracilis Kützing
Stations: 10, 11, 13; DS 105.

Chaetomorpha javanica Kützing
Stations: 3, on coral with *Enteromorpha*.

Chaetomorpha linum (Müller) Kützing
Stations: 4, 11, 13, 28.

Chaetomorpha minima Collins and Hervey
Stations: 3, 15, 26, 30.

Chlorodesmis hildebrandtii A. and E. S. Gepp
Stations: 24, a single fragment.

Cladophora patentiramea (Montagne) Kützing?
Stations: 21.

Cladophora crystallina (Roth) Kützing?
Stations: 11, 13, 15, 21.

Cladophora inserta Dickie f. *ungulata* (Brand) Kützing?
Stations: 4, 7, 15, 30; epiphytic on various algae and *Cymodocea*.

Cladophora sp. 1
Stations: 4; DS 55; Rhyne 809, 832. Plants are similar to an undetermined species from Rongelap (Taylor 1950).

Cladophora sp. 2
Stations: 13, 28, on *Dictyota*, a *Pecten* shell and calcareous debris. Plants are microscopic, prostrate with branching only in the plane of the substrate; rhizoids terminating in a bulbous cell that deeply penetrates the substrate or adheres to the surface of other algae.

Cladophora spp.
Three additional species of *Cladophora* are being studied.

Cladophoropsis sp. 1
Stations: 10, 11, 15, 21, on *Struvea* and *Microdictyon*. Plants attached by the expanded to crenulate basal portion on the original coenocyte; in one plant basal portion developing colorless rhizoidal filaments; mature segments generally dichotomously branched, 90 μ diam., to 575 μ long; ultimate segments at least in younger parts moniliform without reference to septa; plastids discoid or associated.

Cladophoropsis sp. 2
Stations: 26, in algal turf. Plants fragmentary but resemble *C. suddanensis* Reinbold.

Cladophoropsis sp. 3
Stations: 26, on *Caulerpa*. Plants fragmentary and poorly developed but resemble *C. gracillima* Dawson.

Cladophoropsis sp. 4
Stations: 9b, 21. Plants creeping to erect, branching irregular to pectinate, often ending in rhizoids; rhizoidal segments 37-45 μ diam., 250-380 μ long, rarely to 2mm long; lower axis segments 100 μ diam., 250-270 μ long, obtuse.

Codium arabicum Kützing
Stations: 20, 26; DS 123.

Codium edule Silva
Stations: 24, 26: DS 22.

Derbesia attenuata Dawson
Stations: 24, 26, in algal turfs.

Derbesia sp. 1
Stations: 26, in algal turfs. Plants have smaller dimensions than *D. marina* (Lyngbye) Kjellman.

Derbesia sp. 2
Stations: 30; DS 73. Plants erect to 5mm not particularly lax irregular creeping axes 25-37 μ diam., erect axes dichotomous to alternate; reproductive axes 75 μ diam. tapering to 28 μ obtuse, rarely with septa; sporangia oval, 90 μ diam., 142 μ long at maturity; pedicle, as limited by septa, 20 μ diam., 12 μ long; plastids discoid, 5 μ diam.

Dictyosphaeria cavernosa (Forskål) Børgesen
Stations: 4, 5b, 18, 30; DS 40 as *D. intermedia* var. *intermedia*; Rhyne 830.

Enteromorpha compressa (L.) Greville
Stations: 3, 9b, 16; DS 68.

Enteromorpha prolifera (Müller) J. Agardh subsp. *prolifera* typus III
Stations: 23, floating in calm water.

Enteromorpha spp.
Five additional species of *Enteromorpha* from the reef flat are being studied.

Entocladia viridis Reinke
Stations: 4, 5c, 15, 30; in the sheath of *Polysiphonia, Champia, Lurencia, Schizothrix* and on hydroids.

Gomontia polyrhiza (Lagerheim) Bornet and Flahault
Stations: 4, 5a, 9b; in corals, shells, and calcareous debris.

Gomontia sp.
Stations: 16, 28; in shells. Axes and branching highly irregular, cells 12-18 μ diam., 20-55 μ long, some empty others with spores, but not other wise modified as sporangia, spores round 5 μ.

Specimens of *Halimeda* are being studied by Colinvaux but the following have been reported.

Halimeda discoidea Decaisne
Stations: DS 1.

Halimeda copiosa Goreau and Graham
Stations: 15, 21. See Colinvaux (1968), as *H. hederacea*.

Halimeda incrassata (Ellis) Lamouroux
Stations: DS 26, 75, 108; Barton, Addu.

Halimeda opuntia (L.) Lamouroux
Stations: DS 2a, 3, 4; Barton, Addu.

Halimeda tuna (Ellis and Solander) Lamouroux
Stations: Barton, Suvadiva.

Microdictyon pseudohapteron Gepp and Gepp
Stations: 5a, 9b, 11, 13, 15; *M. pseudohapteron* f. *luciparense* Setchell is the only Maldive alga reported by Newton (1953) for the John Murray Expedition. It was dredged from the lagoon floor of Mulaku (Mulakadu) Atoll.

Microdictyon sp. 1
Stations: 11, 13, 15; several unreported fragments are in the British Museum collection from the lagoons of Addu and Suvadiva. They were dredged during the J. Stanley Gardiner Expedition. Plants resemble *M. agardhianum*.

Microdictyon sp. 2
Stations: 10, 21. Plants belong to the Eumicrodictyon section of the genus.

Microdictyon sp. 3
Stations: 21, on Halimeda. Plants belong to the Calodictyon section of the genus and resemble *M. japonicum*.

Neomeris annulata Dickie
Stations: 21.

Neomeris mucosa Howe
Stations: DS 102.

Ostreobium brabantium Weber Van Bosse
Stations: 4, 17, 28; in *Pecten* and *Tellina* shells, dead corals and in coralline algae.

Ostreobium reineckei Bornet
Stations: 4, 9b, 28, 16, 17, 19; in *Pecten* and other shells, dead corals and coralline algae.

Pseudochlorodesmis furcellata (Zanardini) Børgesen
Stations: 7, on *Halimeda*.

Rhipidiphyllon?
Stations: 5b, on *Valonia*. Plants as *R. reticulatum* (Askenasy) Heydrich but anastomosing with distal crenulations or fibulae rather than annulations.

Spongomorpha?
Stations: 6, 30; Plants are boodleoid with terminal cells from 1.1 to 2.7mm long.

Struvea anastomosans (Harvey) Piccone et Grunow ex Piccone
Stations: 3, 6, 10, 18, 21, 24, 26.

Tydemania expeditionis Weber Van Bosse
Stations: Glomeruliferous plants 3, 17, DS 32; Flabellate plants 6.

Udotea javensis (Montagne) A. and E. S. Gepp
Stations: 21, 24, 26, 28, 30.

Udotea orientalis A. and E. S. Gepp
Stations: DS 15; Rhyne 800, 817. Probably a seasonal alga.

Ulvella lens Crouan
Stations: 4, 5b, on *Cymodocea, Chaetomorpha* and *Dictyosphaeria*.

Valonia aegagropila C. Agardh
Stations: 5a, 30.

Valonia utricularis (Roth) C. Agardh
Stations: DS 103, 111; Barton, Suvadiva.

Valonia ventricosa J. Agardh
Stations: 6, 7, 10, 11, 12, 15, 21; DS 52.

Valoniopsis pachynema (Martens) Børgesen
Stations: 5; DS 99, 118, as *Cladophoropsis* sp.

Phaeophyceae

Dictyopteris repens (Okamura) Børgesen
Stations: 11, 12, 13, 15, 26; Barton, Suvadiva, as *Haliseris delicatula*. Some plants are monostromatic and may represent a second entity.

Dictyota patens J. Agardh
Stations: 7, 24, 26, 30; DS 5b, as *Dictyota* sp.

Dictyota bartayresii Lamouroux
Stations: Rhyne 789, 789b, 820; DS 5a, as *D. friabilis;* Barton, Addu.

Dictyota spp.
Two additional species of *Dictyota* including DS 70 [as *D. friabilis* in Tsuda and Newhouse (1966)] are being studied.

Ectocarpus indicus Sonder
Stations: 9b, 25, 26, 30. Plants well developed at Addu only.

Ectocarpus irregularis Kützing
Stations: 12, on *Porolithon.*

Ectocarpus variabilis Vickers
Stations: 25, on *Thalassia.*

Hydroclathrus clathratus (Bory) Howe
Stations: DS 45; Rhyne 890b. Probably a seasonal alga.

Padina commersonii Bory
Stations: 4, 7, 15, 21.

Padina sp.
Stations: 25; DS 17. Plants are thicker than the previous and oogonia are non indusiate.

Pocockiella variegata (Lamouroux) Papenfuss
Stations: 4, 5b, 6, 7, 9b, 10, 11, 12, 15, 21, 24, 26, 29.

Rosenvingea intricata (J. Agardh) Børgesen
Stations: Rhyne 798a on *Thalassia.* Probably a seasonal alga.

Sargassum sp.
Stations: 5b, on *Lithophyllum.* Plants to 1 cm high.

Spatoglossum sp.
Stations: 15. Plants lack a differentiated epidermal layer but otherwise resemble *S. cornigerum* J. Agardh.

Sphacelaria novae-hollandiae Sonder
Stations: 5a, 12, 25, 26.

Sphacelaria tribuloides Meneghini
Stations: 13, 24, 30. Germinating propagulae are common, but mature plants are rare and poorly developed.

Turbinaria ornata (Turner) J. Agardh var. ornata f. *evesiculosa* (Barton) Taylor
Stations: 4, 7, 20, 24, 26, 29, in well protected crevices and *Cymodocea* beds.

Acknowledgment

The cruise of the Stanford University Research Vessel *Te Vega* to the Maldives in 1964 was made possible by the National Science Foundation and the Maldive Government. The scientific party, directed by Dixie Lee Ray, is indebted to N. T. Hasen Didi, Assistant Minister of Home Affairs, who acted as interpreter and guide. The author is grateful to those who examined and identified specimens or sent specimens for study. Among these are Francis Drouet, George Hollenberg, James Price, Charles Rhyne, Roy Tsuda, and Michael Wynne.

References

Aregood, Carol C. and H. E. Hackett. 1971. A new *Dictyurus* (Rhodophyceae-Dasyaceae) from the Maldive Islands, Indian Ocean. *J. Elisha Mitchell Sci. Soc.* 87(3):91-96.

Agassiz, A. 1903. The coral reefs of the Maldives. *Mem. Mus. Comp. Zool. Harvard Univ.* 29:i-xxv, 1-168.

Barton, Ethel S. (Mrs. A. Gepp). 1903. List of marine algae collected at the Maldive and Laccadive Islands by J. S. Gardiner Esq. *J. Linn. Soc. (London), Bot.* 35:475-482.

Colinvaux, Llewellyn H. 1968. New species of *Halimeda:* a taxonomic reappraisal. *J. Phycology* 4(1):30-34.

Dawson, E. Y. 1956. Some marine algae of the southern Marshall Islands. *Pacific Sci.* 10:25-66.

---------- 1957. An annotated list of marine algae from Eniwetok Atoll, Marshall Islands. *Pacific Sci.* 11:92-132.

Foslie, M. 1903. The Lithothamnia of the Maldives and Laccadives. In Gardiner, J. S. 1903. *The fauna and geography of the Maldive and Laccadive Archipelagoes.* 1:460-471.

---------- 1907. The Lithothamnia. In Gardiner, J. S. 1907-1936. Percy Sladen Trust Expedition to the Indian Ocean in 1905. 1 (2) *Trans. Linn. Soc. (London),* Second Ser. *Zool.* 2:177-192.

Gardiner, J. S. 1903. *The fauna and geography of the Maldive and Laccadive Archipelagoes.* Vols. 1-2. Cambridge University Press, Cambridge.

Hackett, H. E. 1969a. *Marine algae in the atoll environment: Maldive Islands.* Duke Univ. Unpub. dissertation.

---------- 1969b. Marine algae in the atoll environment: Maldive Islands. *Proc. Int. Seaweed Symp.* 6:187-191.

Hass, H. 1962. Central subsidence. A new theory of atoll formation. *Atoll Res. Bull.* 91: 1-4.

Newton, Linda M. 1953. Marine algae. *John Murray Expedition Reports,* 9(5):395-420.

Sigee, D. C. 1966. Preliminary account of the land and marine vetegation of Addu Atoll. *Atoll Res. Bull.* 116:61-74.

Stoddart, D. R., ed. 1966. Reef studies at Addu Atoll, Maldive Islands. Preliminary results of an expedition to Addu Atoll in 1964. *Atoll Res. Bull.* 116:1-122.

Tracey, J. I., Jr., P. E. Cloud and K. C. Emery. 1955. Conspicuous features of organic reefs. *Atoll Res. Bull.* 46:1-3.

Tsuda, R. T. and J. Newhouse. 1966. Marine benthic algae from Addu Atoll, Maldive Islands. *Atoll Res. Bull.* 116:93-102.

United States Naval Oceanographic Office. 1951. *Sailing directions for the west coast of India.* Hydrographic Office Publ. 63.

Weber Van Bosse, Anna and M. Foslie. 1904. The Corallinaceae of the Siboga Expedition. *Siboga Expeditie* 61. E. J. Brill, Leyden.

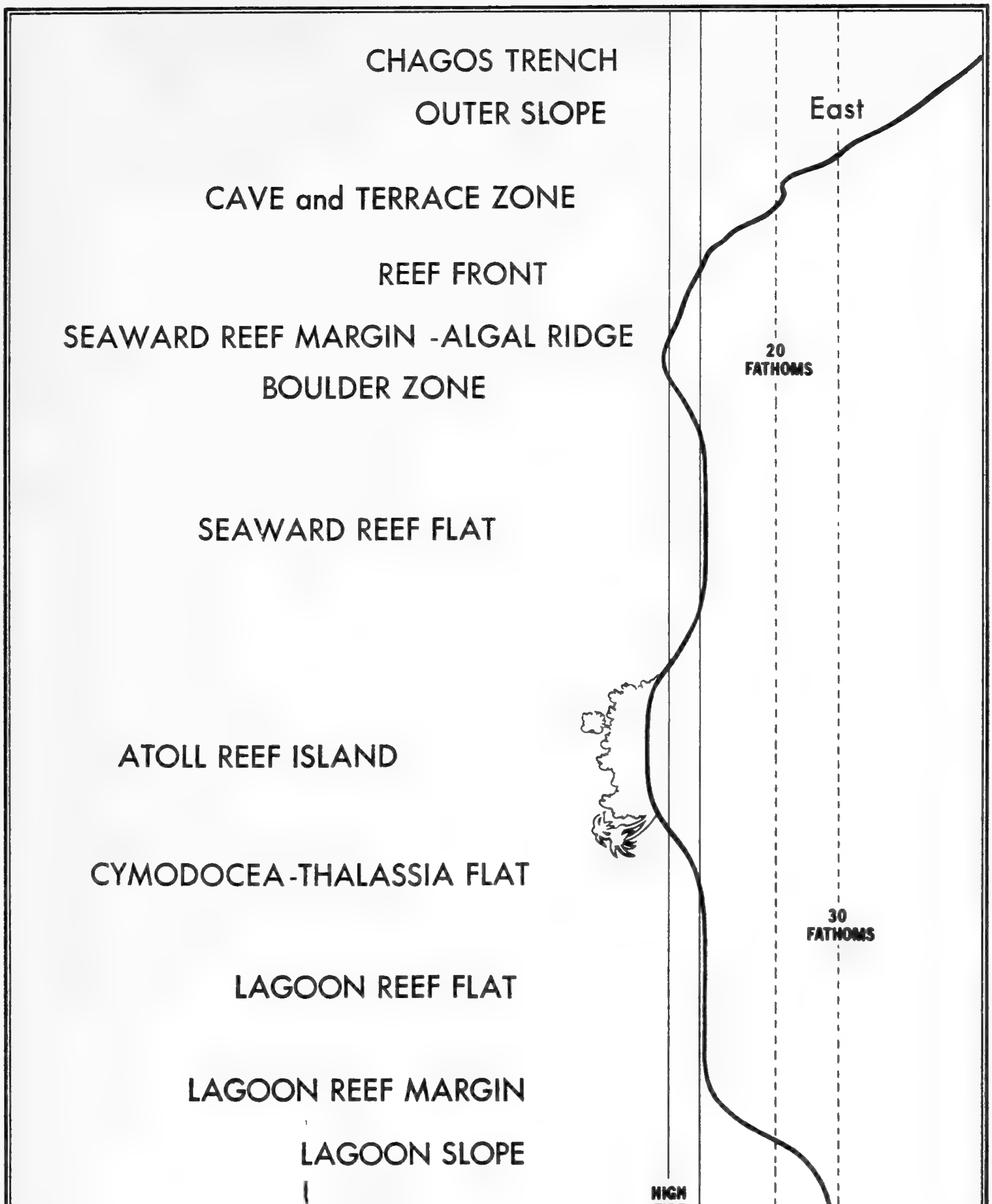


Fig. 1. A composite cross section of the conspicuous features of a large Maldivian Atoll from the eastern side of the archipelago. Eastern half of the atoll.

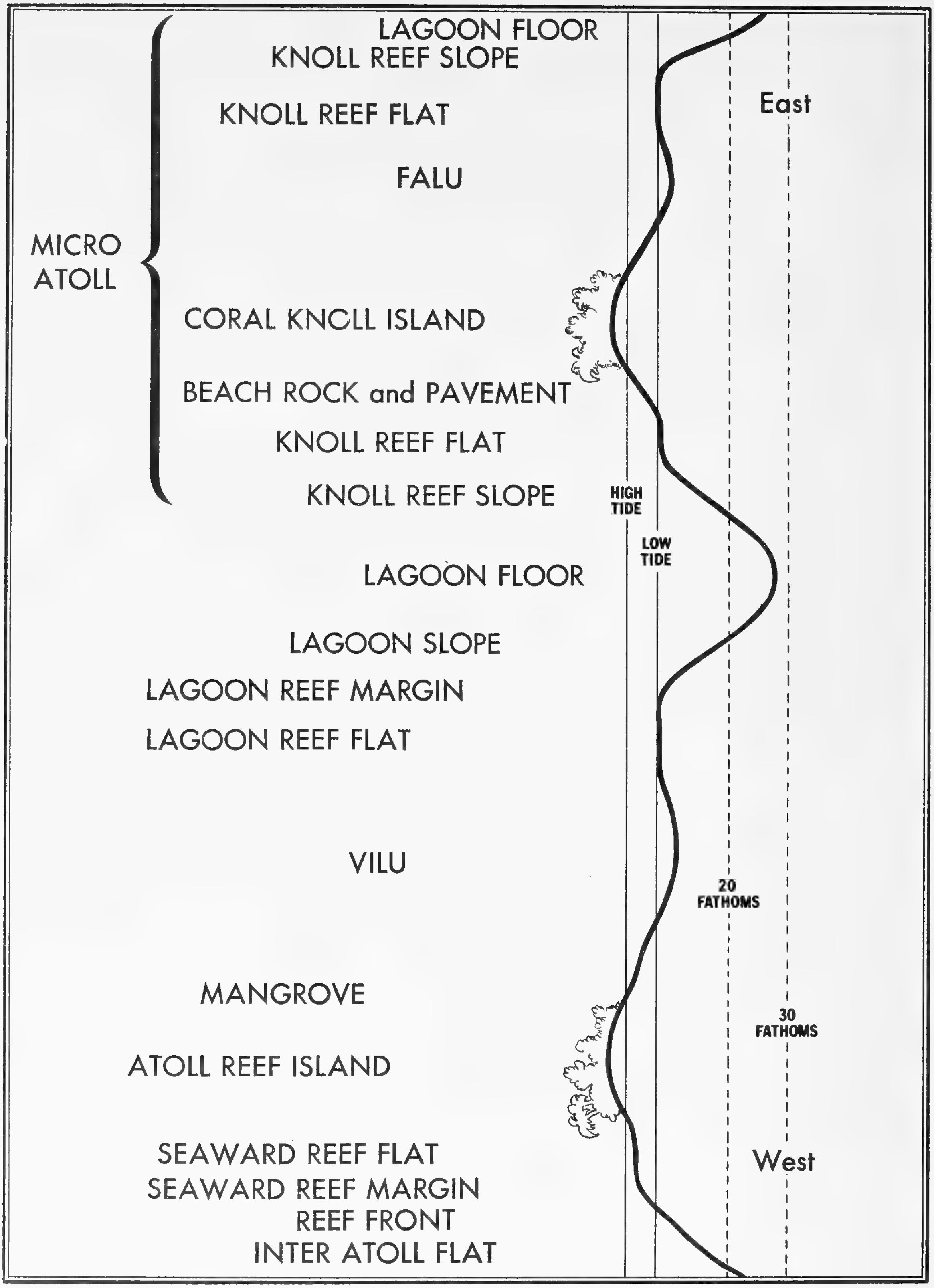


Fig. 2. A composite cross section of the conspicuous features of a large Maldivian Atoll from the eastern side of the archipelago. Western half of the atoll.

ATOLL RESEARCH BULLETIN
NO. 211

THE BENTHIC ALGAL COMPOSITION, STANDING CROP, AND PRODUCTIVITY OF A CARIBBEAN ALGAL RIDGE

by Judith L. Connor and Walter H. Adey

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

THE BENTHIC ALGAL COMPOSITION, STANDING CROP, AND PRODUCTIVITY OF A CARIBBEAN ALGAL RIDGE [1]

by Judith L. Connor and Walter H. Adey [2]

Abstract

The distribution and standing crop of benthic algal species on a Caribbean algal ridge (St. Croix) and its associated carbonate pavements is discussed and contrasted with that of other eastern Caribbean algal ridges and a Pacific algal ridge. Mean standing crops of 3 kg/m^2 (wet weight) and a species richness of about 40 species (for ten 0.25 m^2 samples) were encountered on St. Croix. Non-calcified or fleshy algae are greatly reduced in standing crop with depth away from the high wave energy ridge crests and species richness increases. This is correlated with the greater grazing abilities of fish and invertebrates under less turbulent conditions.

On reefs of typical lower eastern Caribbean islands, only where the force of water movement across intertidal algal ridges prevents intense grazing by fish and echinoids are general high levels of algal standing crop and productivity developed. However, in the more eutrophic waters of higher islands and where wave action is greater, dense standing crops of larger fleshy algae can also extend sublittorally to depths of at least 10 meters. We suggest that the extensive filling of grazing niches in tropical reefs and a general retreat of plant tissues to protective carbonate structures has caused a reduction of primary productivity in typical reef environments.

---

[1] Contribution no. 25 from the West Indies Laboratory of Fairleigh Dickinson University. This project was supported by the Smithsonian Research Awards Program.

[2] Smithsonian Institution, Washington, D.C. 20560.

(Manuscriptreceived March 1975 -- Eds.)

Introduction

The windward reef margins of large numbers of Pacific atolls and some high islands are rimmed by an algal ridge, a partly intertidal and supratidal calcareous reef framework built primarily by crustose coralline red algae. Less well known are the scattered but locally abundant occurrences of algal ridges in the Caribbean and tropical Atlantic. Adey and Burke (1976) describe the distribution of algal ridges in the eastern Caribbean, and Adey (1975) treats in detail the morphology, structure and geological history of the well-developed set of algal ridges on St. Croix. The latter author also summarizes the more important literature on algal ridges. In this paper, we describe the fleshy algal flora of the St. Croix algal ridges and its richness and ecology in terms of standing crop.

Few studies have been done on the standing crops of benthic marine algae on algal ridges or coralline-rich reef areas (coralline pavements). Taylor (1950) describes the difficulty of collecting on the Bikini ridge (Marshall Is.). He gives an account of removing algae from a particularly thick zone (a few millimeters to a centimeter in thickness) on the ridge. Dahl (1971) describes an algal turf association on the fringing reef flat of American Samoa. His algal associations of low standing crop and high diversity decrease in coverage across the reef flat to the seaward side where first crustose algae and then, further seaward, living corals predominate. Quantitative biomass measurements were not given by Dahl. Another Pacific account, Soegiarto's work on Kaneohe Bay, Hawaii (in Smith et al., 1973) indicates that standing crop and algal diversity are greatest in the reef flat surf zone, where water movement is greatest (250 g/m^2 dry weight) and decrease in all directions from there.

Doty's (1969, 1971) studies on the standing crop on an algal ridge and associated coralline pavements off Waikiki Beach, Hawaii are among the few detailed quantitative studies treating the attached flora of a coralline reef. Using Doty's data for November, 1967 as being about average for the entire period covered, the mean standing crop reaches a maximum of about 3400 g/m^2 wet weight on the algal ridge and a minimum of about 1300 g/m^2 in the deeper zone immediately behind the ridge (approximately 1 meter deep).

The upstream-downstream method of determining the organic productivity of an ecosystem has become a standard method of marine biology. Johannes et al. (1972), Gordon and Kelly (1962) and Odum (1956) discuss the method and cite its use on several reef structures in the Pacific. We have applied upstream-downstream analysis of dissolved oxygen to determine the gross and net organic productivity of a single lobe of an algal ridge on St. Croix.

Site Descriptions and Methods

Our study of fleshy benthic algae distribution was conducted on several of the algal ridges along the eastern shore of St. Croix. The collections were especially concentrated on the Boiler Bay algal ridge in the northeast (Fig. 1).

The south shore algal ridges are more or less directly exposed to a prevailing ESE trade wind of 10-20 knots and to seas with wave heights of 1-2 m. The maximum elevations of these mostly actively growing ridges is about 20-50 cm above mean low water spring tide levels (m.l.w.sp.). Benthic algae were removed from quadrats located on Robin, Beach and Isaacs Ridges (Fig. 1).

The Boiler Bay algal ridge, in an intermediate stage of development, consists of a series of 30-35, more or less horseshoe-shaped coralline frameworks ranging in diameter from about 50 m to as little as 2-3 m. For convenience of reference, the larger of these "boilers", "microatolls" or algal ridge "lobes" are named as reefs in figure 2. The Boiler Bay algal ridge, essentially in its present plan, was actively growing from about 2000 to 500 years before present. However, wave action became blocked by growth of a coral reef at the mouth of the bay, and as surface degradation by borers exceeds carbonate accretion by corallines, the ridge is slowly being eroded. The trade wind swell is refracted about 90° over the coral reef and into Boiler Bay, and at the present time wave heights seldom exceed 30 cm. Maximum elevations of the Boiler Bay ridge now range from 5-10 cm above m.l.w.sp. on West End Reef to 17 cm above m.l.w.sp. on Shark Reef, though they were probably somewhat higher in the past.

Distinctive zones of crustose coralline algae, coral and coralline-coral pavement are visible on and around the ridges and were delineated by color patterns on aerial photographs. Color patterns on the ridges and the surrounding pavements are often due to the fleshy algae populations peculiar to each zone, which in turn are largely dependent on depth, wave action and the grazing of animals. Eight distinct algal zones were determined and are described below. Zones 1 to 4 lie on the coralline-constructed algal ridge; the remaining zones lie on the associated carbonate pavements or other rock as described. The zone locations in Boiler Bay are indicated in figures 3 and 4. Detailed maps of the area, along with the methods used in mapping, are given in Adey (1975).

Zone 1 is the horizontal strip of algal ridge which lies above mean low water spring tide levels. Between wave crests, it is potentially exposed to desiccation and intense sunlight, though the wave wash is rather constant and severe drying did not occur during our two year stay in St. Croix. Zone 1 is characterized by a turf of Rhodophyta species up to 10 cm thick dominated by *Hypnea* spp., *Laurencia* spp., *Jania* spp., *Amphiroa* spp. and *Gracilaria mammillaris*.

Smaller amounts of other reds, as well as scattered clumps of *Sargassum* spp., *Colpomenia sinuosa* and other Phaeophyta with occasional small Chlorophyta species are also present.

Zone 2 lies at 0 to about 30 cm below m.l.w.sp. and slopes gently shoreward, averaging about 15 cm in depth. The substrate in this zone is also dominantly coralline algae, though an occasional *Porites astreoides* is also present. Zone 2 is chiefly populated by *Halimeda opuntia, Laurencia papillosa* and *Gelidiella acerosa,* though *Pterocladia americana* and *Jania* spp. are also important.

Below zone 2, the algal ridge continues to slope shoreward, tending to form open-backed basins behind each boiler or lobe with depths of about 30 to 60 cm. These basins are designated as zone 3. Here, *Porites astreoides* occupies about 15% of the surface area, and there are also scattered sand pockets in the coralline substrate. The flora here is similar to the second zone, but *Laurencia papillosa* and *Halimeda opuntia* are reduced and the total biomass of fleshy algae is one third less than in the second zone.

The vertical seaward faces of the algal ridge at about 1 to 1.5 m depth were designated zone 4. This is a relatively smooth coralline surface with a light cover of fleshy algae of many small species, the most obvious being *Dictyopteris delicatula.* All quadrats from zone 4 were taken centered at about 0.5 m below m.l.w.sp.

Zone 5 occurs on the nearly flat and irregular seaward margin of the fore-ridge carbonate pavement at depths of 3.5 to 4.5 m. The substrate in this zone is a largely cor-algal pavement of dead corals cemented together by crustose corallines, foraminifera and probably submarine cementation of sediment. A few live corals, *Porites astreoides, Porites porites,* and *Siderastrea* spp., are also present. The dominant algae are *Halimeda opuntia, Dictyota divaricata, Amphiroa tribulus* and *Halimeda tuna.*

Zone 6 is also predominantly a cor-algal pavement, but about 11% of the surface is covered by the same living corals that characterize zone 5, *Porites astreoides* being especially important. This zone occurs around the sides and shoreward margins of the ridge lobes at depths of 0.5 to 1.5 m. The most abundant algae here are *Halimeda opuntia, Dictyopteris delicatula, Dictyota divaricata, Dictyota dentata, Sargassum vulgare* and *Jania* spp., but numerous other species also occur in small amounts.

Zone 7 lies in the shallow water (0.5 - 1.0 m) near shore landward of the algal ridge, where a band of carbonate and terrigenous cobbles and pebbles occurs along much of the shore of Boiler Bay. Some corallines and corals also occur here, but in rather small amounts. In this band, the dominant algal species are *Jania adherens, Padina sanctae-crucis, Sargassum vulgare, Halimeda opuntia* and *Cladophoropsis membranacea.*

Zone 8 occurs on the beachrock which runs parallel to the shore in the western and eastern sections of Boiler Bay. This zone is frequently well above mean low water, and since it is partly protected from wave action by the algal ridge, it is somewhat more subject to desiccation and temperature and salinity extremes. However, our quadrats were taken below mean low water springs at depths of about 0 to 0.5 m. Much of zone 8 is characterized by a turf of *Hypnea musciformis, Laurencia papillosa* and other Rhodophyta. However, at the east end of Boiler Bay, the Chlorophyta dominate this zone, particularly *Halimeda incrassata, Halimeda opuntia* and *Dictyosphaeria cavernosa*. At the west end of the bay, the breachrock is covered predominantly with *Sargassum vulgare* with considerable amounts of *Sargassum platycarpum, Dictyota dentata* and *Chaetomorpha linum*. Because of this difference in the two areas of beachrock and our inadequate sampling for the zone, we do not feel that we have properly characterized the algal populations of zone 8.

In each of the above zones, quadrats were subjectively chosen from several algal ridge lobes and their associated pavements as being typical in algal cover for that particular zone. Macroscopic benthic algae were removed as well as chunks of substrate from within a 0.25 m^2 area. The substrate was carefully examined for the smaller species and all algae collected was sorted, identified and weighed for wet biomass. Taylor (1960) was used extensively for identifications. Skeletal carbonate for *Jania, Amphiroa, Halimeda* and *Pencillus* was calculated using the data of Vinogradov (1953). The standing crops of crustose coralline, algal symbionts and boring algae are not included in this data.

Upstream-downstream dissolved oxygen analysis was applied to Reference Reef, one lobe of the Boiler Bay algal ridge (Figs. 2, 5 & 11). Sampling was accomplished at low water during spring tides when quiet weather permitted a gentle flow of seawater over the ridge with each wave crest. At that time, zone 1 is exposed except during a wave crest and zone 2 is exposed with each wave trough. The water flows southwestward over Reference Reef into the back-ridge lagoon. The boundary of the flow across the ridge (see figure 5), and the flow rates, were measured with standard float bottles. Flow volumes were calculated through section B-B' of the effluent channel. Because of the restricted area involved, the conjunction of spring tides, small waves and light ENE winds was required to provide a measurable channelization of effluent and a well defined area of measurement, as well as to reduce the possibility of significant atmospheric oxygen input from breaking waves. There was therefore often a considerable waiting period between water sample collections. Dissolved oxygen measurements were accomplished using standard Winkler techniques (Strickland and Parsons, 1968).

Oxygen exchange was also studied on 100 cm^2 segments of coralline and corals with their attached algal cover, which had been removed from

231-339 O - '77 - 6

Boiler Bay just prior to testing. Polarographic electrodes were used with a precision blood oxygen instrument (Radiometer model no. PHM-27) and a salt water chamber maintained at $\pm$ 0.1^{o}C (see Adey, 1973). Full sunlight (early April) was employed, and following testing with an entire sample, the fleshy algae were removed and the coral or coralline substrate was tested again.

Results

A list of the algal species commonly encountered in each quadrat and their standing crops is given in tables 1 and 2. The standing crops of all algae for the Boiler Bay algal ridge are shown in figure 6 according to zone. The total number of species encountered and the number of quadrats are also indicated. Fleshy algae are treated separately from those with carbonate skeletons. Summary graphs of the mean standing crops, relative to zone, exclusive of rare or infrequent species, are given in figures 7 through 9. Those quadrats taken from Robin, Beach and Isaacs Ridges on the south shore are summarized in figures 10A and 10B.

Winkler oxygen values obtained for the Reference Reef sampling stations shown in figure 5 are given in figure 11. On each sampling occasion, daytime oxygen levels increased as water flowed over the ridge and nighttime levels decreased. The oxygen thus produced or consumed by the ridge organisms and net and gross productivity in g carbon/m^2/day (translated by g O_2/m^2 . 0.3, Ryther, 1956) are calculated in table 3. Day and nighttime upstream samples were not taken at the same point, and the possible effect of this is discussed below.

Another estimate of the productivity of Reference Reef was determined from the laboratory polarographic electrode study of small samples. The rate of productivity for each zone of Reference Reef was calculated as the product of the total surface area of that zone times the photosynthetic and respiratory rate derived in the laboratory from the 100 cm^2 segment from the same zone. These calculations are shown in table 4.

Our range of gross productivity for Reference Reef is compared with other studies in table 5.

Discussion

The Waikiki Beach study (Doty, 1968) of algal standing crops included algal ridge crest and back ridge or reef flat areas. For comparison, we have plotted the Waikiki data for November 1967 in figure 12. This month shows about an average level of standing crop for the 17 month period (see Doty, 1971).

In terms of total algal standing crop (not including crustose coralline, borers or symbionts), from the algal ridge crest back into

the lagoon, Waikiki and Boiler Bay are quite similar. The peak of standing crop occurs on the ridge crest in both cases and this is markedly reduced on the back ridge pavements. The shallower Waikiki back ridge pavement has a higher standing crop than that of Boiler Bay. However, the most striking difference is an apparent lack of a beach rock and its accompanying secondary peak of standing crop at Waikiki. Even in the total number of macroscopic species present, these two areas are remarkably similar, Boiler Bay averaging about 33 species/zone (see figure 6) and Waikiki about 37 species/zone, the difference being easily attributable to collecting pressure (see figure 14).

In detail, however, the two areas are remarkably dissimilar. On the Boiler Bay algal ridge, the red algae dominate strongly, forming 48-62% of the standing crop. (If the crustose corallines were to be included, the dominance would be considerably greater.) This high level of red algal standing crop is not concentrated in a few species, but in over eight species of *Laurencia, Hypnea, Gracilaria, Gelidiella, Pterocladia, Jania* and *Amphiroa*. On the pavements surrounding the ridge (zone 6) and on the fore-beach cobbles (zone 7) this dominance is reduced, but still the red algae make up 20-40% of the standing crop. It is only in some areas of the beach rock (zone 8) that the red algae are largely replaced by the green alga *Halimeda* or the brown alga *Sargassum*.

In contrast, a number of species of *Laurencia, Hypnea* and *Gracilaria* are present on the Waikiki reef, but none of these exceed a mean of 80 g/m^2 in any one zone. Although *Spyridia filamentosa* reaches mean values of nearly 200 g/m^2, only *Acanthophora spicifera* reaches dominant levels. However, virtually all of the red algal standing crop that is present occurs on the back ridge flat, especially near shore. The 23 species of red algae in the quadrats on the Waikiki algal ridge proper formed only .04% of the standing crop in November, 1967, while in Boiler Bay's equivalent zones, 31 species (in quadrats) formed 41% of the standing crop.

Green algae are not important on the algal ridge crests in either Boiler Bay or Waikiki Beach. However, on the back and fore-ridge pavements and near shore in both areas, the greens become conspicuous. The 30-40% of green standing crop in back ridge and beach rock at Boiler Bay were mostly *Halimeda* spp. However, *Caulerpa, Cladophoropsis, Valonia* and *Dictyosphaeria* occur at mean levels of 20-160 g/m^2. The 20% of the standing crop in back ridge and shore Waikiki contains considerable *Halimeda*, but nearly equal amounts of *Dictyosphaeria cavernosa*. *Ulva reticulata*, near shore, is also important, perhaps due to higher pollution levels.

In contrast to the situation in Boiler Bay, the Waikiki ridge standing crop is almost entirely composed of brown algae: three species of *Sargassum*. These three species occur in varying amounts across the reef flat to the shore, and it is only in the zone 30 meters from shore, where *Sargassum polyphyllum* and *Acanthophora spicifera* share most of the biomass, that the brown algal dominance of the standing

crop is challenged. At least three species of *Sargassum* occur on the Boiler Bay ridge, but only in a single quadrat did they occur at levels of more than a few grams. *Sargassum* is generally more important on the beach rock and *Padina sanctae-crucis* on the cobble zone near shore. Otherwise, *Dilophus, Dictyopteris* and *Dictyota* are all important minor elements on the pavements around the Boiler Bay ridges and may occasionally form blooms. In Hawaii, *Dilophus* does not occur, and at Waikiki relatively few *Dictyota* and *Dictyopteris* occur as compared to other Hawaiian areas (I.A. Abbott, personal communication).

In the context of these striking differences, it is interesting to examine the standing crop of the exposed algal ridges on the south shore of St. Croix. Green algae are virtually absent from the highest of these ridges as they are at Waikiki. Also, the brown algal standing crop, largely in the form of *Sargassum vulgare,* exceeds that of the red algae which consists mostly of three species of *Laurencia*. In the back ridge zones 2 and 3, the *Sargassum* drops rapidly in abundance. Even though it tends to be replaced by *Dictyopteris,* red algae (still mostly *Laurencia* spp.) begin to dominate again. This suggests that on algal ridges subject to very high wave energies, reds may be replaced by *Sargassum*. The considerably higher and more exposed algal ridges on the southeast shore of Martinique (studies in progress) show a similar relationship. There, the highest ridge tops, at > 1 m m.l.w.sp., are nearly bare, while the low crests and surrounding highly turbulent pavements have high standing crops of *Sargassum*. While Waikiki is not directly exposed to the trade wind, as are the southeastern St. Croix ridges, it does often receive a very large South Pacific swell. Boiler Bay, on the other hand is largely blocked by the northern Virgin Islands and rarely receives the equivalent large swells from occasional northerly winds developed from passage of continental fronts ("northers").

Adey (1974) discusses the relationship between exposure, wave action and algal ridge heights. The highest parts of the more exposed St. Croix ridges reach 40-50 cm above mean low water springs, with a mean spring tide range of about 30 cm. During some summer neap tide cycles, the ridge zone 1 can be 20-30 cm above sea level for four to six hours mid-day. Desiccation and heating are likely to be critical on occasional quiet days and, along with mechanical stress during more turbulent weather, probably accounts for the obvious bareness of the higher part of the ridges. These factors probably also account for the difference in standing crop decreasing from 3200 g/m^2 at Boiler Bay ridge crests with an average height of +14 cm to 2680 g/m^2 on the south shore ridges averaging +30 cm high. It seems likely that *Sargassum* species are better able to withstand both the turbulent water conditions and perhaps occasional periods of limited desiccation and heating.

In recent years, it has generally been considered that benthic algal standing crops are considerably lower in tropical than in temperate to boreal areas (see e.g., Taylor, 1960). This has been

variously attributed to low ambient water nutrients, high insolation levels, lack of beds of brown algae or a shift of standing crop to crustose corallines, which are not usually included in standing crop analysis (Bakus, 1969). (Note that Adey and Macintyre (1973) point out that crustose corallines are probably as important in terms of bottom coverage in subarctic-boreal waters as they are in the tropics.) In our studies of the Boiler Bay algal ridge and that of Doty at Waikiki, average wet standing crops up to 3 -3.5 kg/m^2 were found, with individual quadrats ranging up to 5 kg/m^2. On several considerably larger algal ridges and pavements that we are now studying in Martinique, algal standing crops are nearly twice as high. Typical lower intertidal *Ascophyllum, Fucus* and *Laminaria* stands in Norway have a standing crop of about 3.5 kg/m^2 (Baardseth, 1970). Upper sublittoral *Laminaria hyperborea* stands in the British Isles average 5.0 - 6.5 kg/m^2 (Kain, 1971). An especially rich *Gigartina stellata* stand in the lowest intertidal and infralittoral in Maine achieved nearly 10 kg/m^2 in the peak summer season (Burns and Mathieson, 1972). Thus, while perhaps temperate-boreal standing crops of larger algae tend to be higher than those in the tropics, algal ridge and beachrock standing crops (those in turbulent zones) can be similar, and, generally, in the seas around the older parts of the higher, volcanic eastern Caribbean islands (Adey and Burke, 1976) algal standing crops of reef structures are quite equivalent to or perhaps larger than the average for northern shores. While brown algae are less important than reds in the flora of the Boiler Bay ridge, *Sargassum, Dictyota* and *Dictyopteris* are major components. Similarly *Sargassum* actually exceeds the red algae in biomass on the south shore St. Croix ridges while at Waikiki and Martinique, it is highly dominant. Perhaps the main question to which our attention should be directed is not why tropical standing crops of larger benthic algae are so low, but why they only achieve high levels in special situations.

The importance of grazing in the shallow tropical marine environment has attracted considerable interest in recent years. Randall (1961) contrasted the luxuriant intertidal algal crop in Hawaii with the low stubble of the upper sublittoral and attributed it to fish grazing (Acanthuridae, Scaridae and Pomacentridae). The conspicuous vegetation-free halo surrounding tropical reef areas has also been shown to result from either fish (Earle, 1972; Randall, 1965) or echinoid (Ogden, et al., 1973) grazing, and removal of urchins from reef areas can result in massive increases of algal standing crops (Sammarco, et al., 1974). Grazing by urchins in northern waters can also be extremely important in limiting standing crop (Jones and Kain, 1967; Paine and Vadas, 1969). In the northern North Atlantic, Adey is familiar with extended areas, virtually bare of fleshy algae dominated by echinoids and coralline algae, and Lebednik (personal communication) has seen similar areas in the Aleutian Islands. Mead (1970) has suggested that the main group of fish grazers, the percoid fishes, which are tropical and Cenozoic in

evolution are largely responsible for the present reduction of the sublittoral algal "forests" in the tropics. It is difficult to escape the logic of this conclusion - an algal ridge or shallow pavement is a special, turbulent water environment which is usually inaccessible to grazing fish and *Diadema*. A few invertebrates (mostly crabs, snails, limpets and chitons) do graze in this zone, although their effectiveness is apparently limited. *Echinometra* is often abundant on algal ridges and beachrock, however, the wave energy is apparently generally sufficient to largely confine the echinoids to their holes and to feeding on drift (Ogden, Abbott and Abbott, 1974).

Below the shallow highly turbulent levels of the ridges and pavements, the grazing marks of parrot fish, urchins and gastropods are often strikingly apparent on the typically bare coralline or rubble surfaces. In Caribbean waters, grazing, especially by parrot fish, is critically important in the colonization and carbonate buildup of the crustose corallines themselves (Adey and Vassar, 1975; Steneck and Adey, 1976), and probably is an important factor restricting algal ridges to the most exposed windward shores.

Our research group has spent a considerable amount of time in daytime snorkeling around the algal ridges in Boiler Bay. Our collective casual observations on the intensity of fish grazing are as follows: zones 1 and 2 on the ridge, zone 8 on the beachrock and perhaps to a lesser extent, zone 7 near shore are rarely grazed by larger fish. These zones are either exposed in wave troughs or continuously washed by waves. Zone 3, the algal ridge bowl is periodically grazed, sometimes heavily depending on sea conditions. Zones 4 and 6, on the other hand, are heavily and consistently grazed. Not only are these zones easily reached by grazing fish, but cover for the fish is abundant in the form of holes in the pavements and coral structures, especially *Acropora palmata*. Zone 5, the deep pavement, is the zone over which we have greatest disagreement concerning fish grazing pressure. Generally, we do agree that it is less than the pavement zone 6 because of lack of cover for the fish. Periodically, however, it is probably massively grazed, especially by schools of tangs and parrot fish. Figure 13 shows this subjective index of grazing potential plotted against standing crop. Generally there is indicated a strong inverse relationship between the ability of fish to graze effectively and the standing crop of fleshy and filamentous algae.

The upright calcareous algae, on the other hand, show no apparent relationship between grazing pressure and standing crop. Zone 1, no fish grazing, and zone 4, intense grazing, have about the same level of calcareous standing crop. The only striking feature of the plot is the very high standing crop of calcareous algae on the deep fore-ridge pavement, zone 5, as compared to the other zones. This largely results from the abundance of only two species, *Halimeda opuntia* and to a lesser extent *Amphiroa tribulus*. *Halimeda opuntia* has

secondary peaks in zones 2 and 6 and the reason for this distribution pattern is obscure.

In figure 14, the total number of non-calcified algal species for each zone are plotted as a function of the number of quadrats taken (i.e., total area collected for collecting pressure). The Waikiki data of Doty are also included and are converted to 0.25 m^2 quadrats on the basis of total area per zone (see Fig. 12). The relationship indicated further suggests that the larger number of species taken at Waikiki was a result of greater collecting pressure. In figure 15, the Boiler Bay data are plotted, species number/zone as a function of quadrat number/zone. Since species number is a function of collecting pressure, a correction factor is thus derived as shown to correct all zones to 10 quadrats. (Note that a plot of number of species occurring at mean levels of > 1g/.25 m^2 is not or only slightly quadrat dependent in the range that we worked.) Thus, in figure 16, the total number of non-calcified algal species, corrected to 10 quadrats, as well as the number with a standing crop > 1 g/.25 m^2, is plotted as a function of zone. Both measures show a consistent drop in number shoreward.

Proceeding shoreward, daytime temperatures and suspended sediment generally increase markedly in Boiler Bay, a feature very obvious to the swimmer. Equivalent night temperature drops are to be expected, especially in the winter. These physical characteristics are likely responsible for the shoreward drop in species number.

Figure 17 indicates the variations in number of species from the mean total species curve (Fig. 16) for Boiler Bay. Zones 3, 4 and 6 have four to six species above mean levels. These are zones of heavy to intermediate grazing pressure, suggesting that due to a reduction in space competition, grazing has increased richness. On the other hand, the poorly grazed zones, especially 1 and 2, which have a high standing crop are poor in the rarer species. Zone 8 is the chief anomaly in the pattern. If lack of fish grazing is the controlling factor, and this is indicated by a relatively high biomass, one would expect total species number to be low. Ogden, Abbott, and Abbott (1974) found 20% fewer species on the west beachrock in Boiler Bay as compared to the offlying ridge crests. Their extensive search for species should represent a large number of quadrats. We suggest that our species number for zone 8 is too high, probably as a result of insufficient sampling.

In table 5, our range of gross productivity values for Reference Reef are compared with other areas. As is perhaps to be expected, our values for a dominantly algal area are somewhat higher than those previously given for coral reef communities. Also as can be seen in table 4, algal ridge zones 1 and 2 are responsible for 55% of the area productivity, and in terms of those zones alone, the productivity is about 30 g C/m^2/day. The contribution of crustose coralline algae is

indicated as 12.1 g C/m^2/day. This is probably higher than normal, since on the Boiler Bay ridge, the coralline surface is usually shaded by the fleshy algal cover. In any case, it is considerably higher than the previous figure of 1.5 g C/m^2/day given by Marsh (1970).

Because of the critical importance of tide level to our process of taking data on the ridge, it was not possible to take successive oxygen readings at different light levels during a single day. This could however be done on different days as the time of low water springs changes. Presumably our daytime values being taken near noon are maximum levels. On the other hand, Marsh (1970) indicated that in ridge corallines, photosynthesis levels are constant for 10 hours of the day. If this is true for other ridge algae, then our upper value of gross productivity (Table 5) is high by about 15%. The productivity of these ridges and especially the higher ridges of the eastern islands (Adey and Burke, 1976) should be examined in further detail.

Conclusions

The intertidal wave-washed crustose coralline algal ridges of St. Croix, Virgin Islands develop a dense standing crop of fleshy algae and have a gross productivity which is high for the tropical reef environment. In caged areas and areas with considerably greater wave action, especially in the presumably more eutrophic waters around the higher volcanic islands such as Martinique, the standing crop is often denser and also extends to greater depths. In St. Croix, where wave energy is moderate, the heavy coverage of fleshy algae is greatly reduced with depth away from the ridge crests. Thus, lack of intense grazing pressure under turbulent water situations is probably responsible for the rich algal area on the ridges. In a relatively low-turbulence coral dominated reef environment, the maturity of the tropical ecosystem with extensive filling of grazing niches, especially by fish and echinoderms, results in a generally reduced primary productivity. Cenozoic tropical reefs are characterized by coralline algae and hermatypic schleractinian corals. The domination of this combination perhaps resulted from the evolution of grazing bony fish and some echinoid species. Algal ridges, and in some cases exposed beachrock, are specialized turbulent water situations in a carbonate environment where grazing niches cannot be filled either by fish or by the key grazer *Diadema antillarum*.

Given favorable conditions of marine salinity and low levels of marine erosion and suspended sediment, the frequency and extent of fleshy algal-dominated reef environments, as well as the nature of the flora developed, is thus largely dependent upon the strength and constancy of the accompanying trade wind and sea. Since well-developed sublittoral algal pavements are especially prominent around the older parts of the higher eastern Caribbean islands, it is suggested that more eutrophic conditions, with greater algal growth rates, are also critical.

Acknowledgements

Many people helped us in the course of this study, chief among them being our own associates J.M. Vassar, P.J. Adey and R.S. Steneck. N. Buckman-Ogden and J. Ogden, West Indies Laboratory, St. Croix both read the manuscript and offered suggestions for its improvement. I.A. Abbott deserves special thanks for both help with identification problems and for critically reading the manuscript.

References

Adey, W.H. 1973. Temperature control of reproduction and productivity in a subarctic coralline alga. *Phycologia* 12: 111-118.

_____. 1975. The structure and geological history of the algal ridges and coral reefs of St. Croix, U.S. Virgin Is. *Atoll Research Bull.* 187.

_____ & R. Burke. 1976. Holocene algal ridges and barrier reef systems of the eastern Caribbean. *Geol. Soc. Am. Bull.* (In Press).

_____ & I. Macintyre. 1973. Crustose coralline algae: a re-evaluation in the geological sciences. *Geol. Soc. Am. Bull.* 84: 883-904.

_____ & J.M. Vassar. 1975. Succession and accretion rates in Caribbean crustose corallines. *Phycologia* 14: 55-69.

Baardseth, E. 1970. A square-scanning, two-stage sampling method of estimating seaweed quantities. *Norwegian Inst. Seaweed Research Rep.* 33: 1-41.

Bakus, G.J. 1969. Energetics and feeding in shallow marine waters. *Int. Rev. Gen. Exp. Zool.* 4: 275-369.

Burns, R.L. & A.C. Mathieson. 1972. Ecological studies of economic red algae. III. Growth and reproduction of natural and harvested populations of *Gigartina stellata* in New Hampshire. *J. Exp. Mar. Biol. Ecol.* 9: 77-95.

Dahl, A.L. 1971. Ecology and community structure of some tropical reef algae in Samoa. *Proc. Seventh Int. Seaweed Symp.* : 36-39.

Doty, M.S. 1969. The standing crops of benthic frondose algae at Waikiki Beach 1966-1969. *Univ. Hawaii Bot. Science Paper* 11: 1-282.

Doty, M.S. 1971. Antecedent event influence on benthic marine algal standing crops in Hawaii. *J. exp. mar. Biol. Ecol.* 6: 161-166.

Earle, S. 1972. The influence of herbivores on the marine plants of Great Lameshur Bay, with an annotated list of plants. *Los Angeles County Nat. Hist. Mus. Sci. Bull.* 14: 17-44.

Gordon, M.S. & H.M. Kelly. 1962. Primary productivity of a Hawaiian coral reef: a critique of flow respirometry in turbulent waters. *Ecology* 43: 473.

Johannes, R.E., J. Alberts, C. D'Elia, R.A. Kinzie, L.R. Pomeroy, W. Sottile, & W. Wiebe. 1972. The metabolism of some coral reef communities: a team study of nutrient and energy flux at Eniwetok. *Bioscience* 22: 541-543.

Jones, N.S. & J.M. Kain. 1967. Subtidal algal colonization following the removal of *Echinus*. *Helgol. Wiss. Meers.* 15: 460-466.

Kain, J.M. 1971. Synopsis of biological data on *Laminaria hyperborea* *F. A. O. Fish. Sym.* 87: pag. var.

Littler, M. & Doty. 1974. Ecological components structuring the seaward edges of tropical Pacific reefs: the distribution, communities and productivity-ecology of *Porolithon*. *J. Ecol.* 63: 117-129.

Marsh, J.A. 1970. Primary productivity of reef-building calcareous red algae. *Ecology* 51: 255-263.

Mead, G.W. 1970. A history of South Pacific fishes, pp. 236-251. In Scientific Exploration of the South Pacific. *Nat. Acad. Sci. St.* Book No. 309-01755-6 Washington.

Odum, H.T. 1956. Primary production in flowing waters. *Limn. Ocean.* 1: 102-117.

Odum, H.T. & E.P. Odum. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. *Ecol. Monogr.* 25: 291-320.

Ogden, J., D. Abbott, I. Abbott et al., 1973. Studies on the activity and food of the echinoid *Diadema antillarum* Philippi on the West Indian patch reef. *West Indies Lab. Spec. Publ.* 2: 1-96.

Ogden, J., D. Abbott, I. Abbott et al. 1974. Studies on the activity pattern, behavior and food of the herbivorous echinoid *Echinometra lucunter* (Linnaeus) on beach rock and algal reefs at Boiler Bay, St. Croix, U.S. Virgin Is. *West Indies Lab. Spec. Publ.* 4.

Paine, R.T. & R.L. Vadas. 1969. Calorific values of benthic marine algae and their postulated relation to invertebrate food preference. *Mar. Biol.* 4: 79-86.

Randall, J.E. 1961. Overgrazing of algae by herbivorous marine fishes. *Ecology* 42: 812.

______. 1965. Grazing effect on sea grasses by herbivorous reef fishes in the West Indies. *Ecology* 46: 255-260.

Ryther, J.H. 1956. The measurement of primary production. *Limnol. Oceanogr.* 1: 72-84.

Sammarco, P.W., J.S. Levinton & J.C. Ogden. 1974. Grazing and control of coral reef community structure by *Diadema antillarum* Philippi (Echinodermata:Echinoidea): a preliminary study. *J. Mar. Res.* 32: 47-53.

Smith, S., K.E. Chave, & D.T.O. Kam. 1973. Atlas of Kaneohe Bay: A reef ecosystem under stress. *Univ. Hawaii Sea Grant Program.* TR-72-01. 128 pp.

Steneck, R. & W. Adey. 1976. The role of environment in control of morphology in *Lithophyllum congestum,* a Caribbean algal ridge builder. In press.

Strickland, J.D., H. & T.R. Parsons. 1968. A practical handbook of seawater analysis. *Bull. Fish. Res. Bk. Can.* 167. 311 pp.

Taylor, W.R. 1950. *Plants of Bikini and Other Northern Marshall Islands.* Univ. Mich. Press, Ann Arbor. 227 pp. 79 pl.

______. 1960. *Marine Algae of the Eastern Tropical and Subtropical Coast of the Americas.* Univ. Mich. Press, Ann Arbor. 870 pp. 80 pl.

Vinogradov, A.P. 1953. *The Elementary Chemical Composition of Marine Organisms. Sears Found. Marine Res.* 14 (Mem. 2): 1-647.

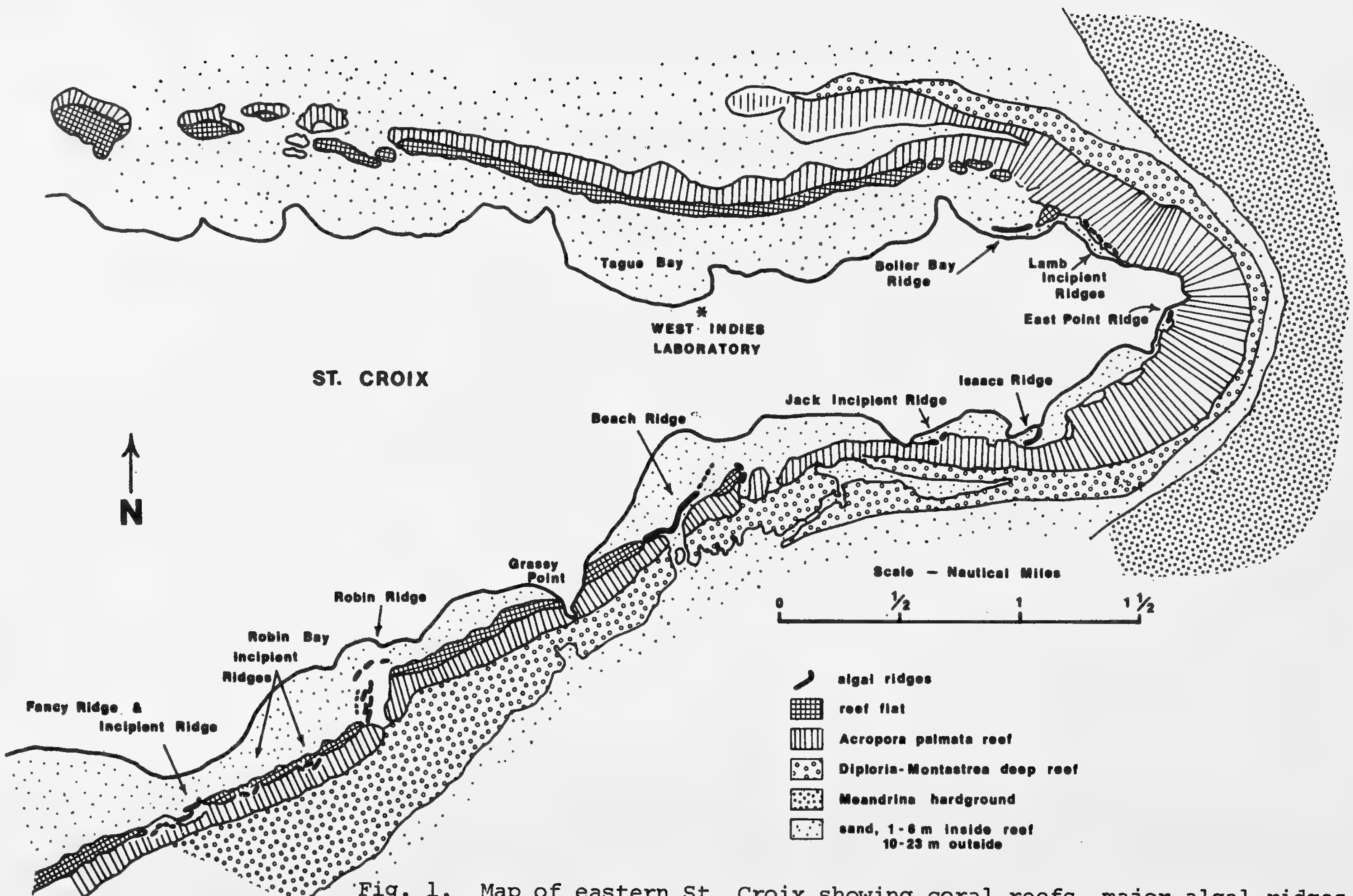


Fig. 1. Map of eastern St. Croix showing coral reefs, major algal ridges and the location of Bioler Bay. (After Adey, 1975)

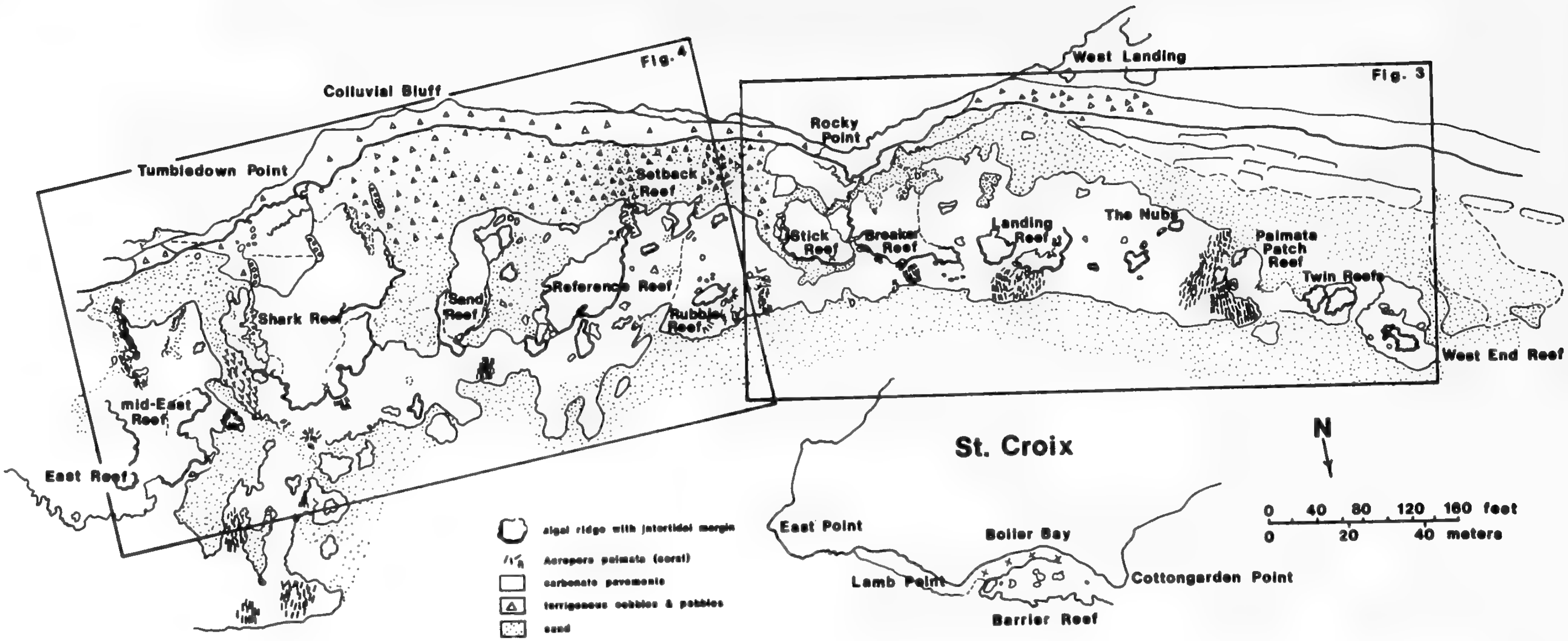


Fig. 2. Map of Boiler Bay, St. Croix showing the locations of the algal ridge lobes (boilers), and the positions of figures 3 and 4. Aerial photo control points indicated by X.

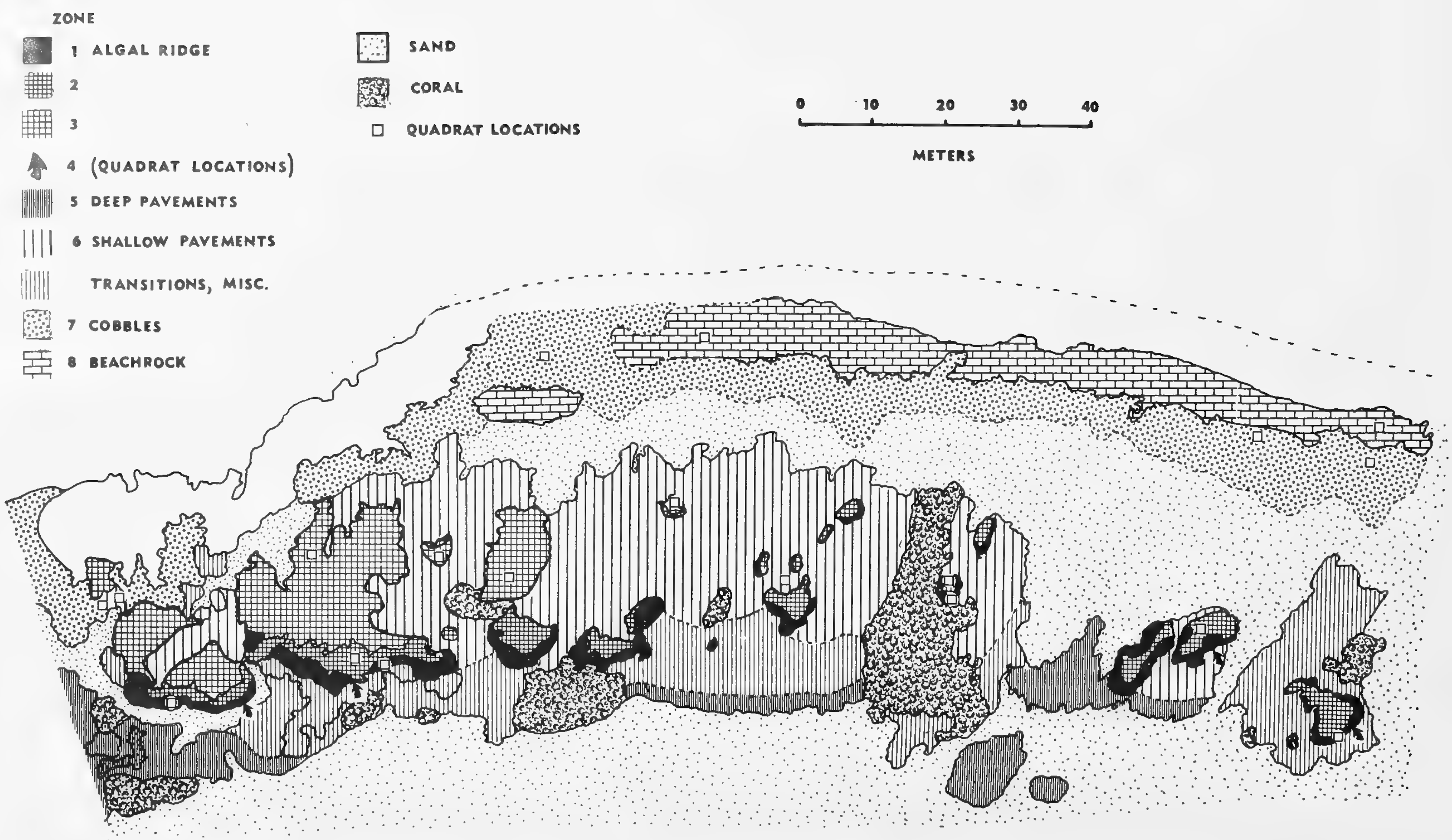


Fig. 3. Western part of the Boiler Bay algal ridge (see figure 2), showing zone positions and the locations of quadrats. This diagram has been simplified from the detailed maps of Adey, 1974.

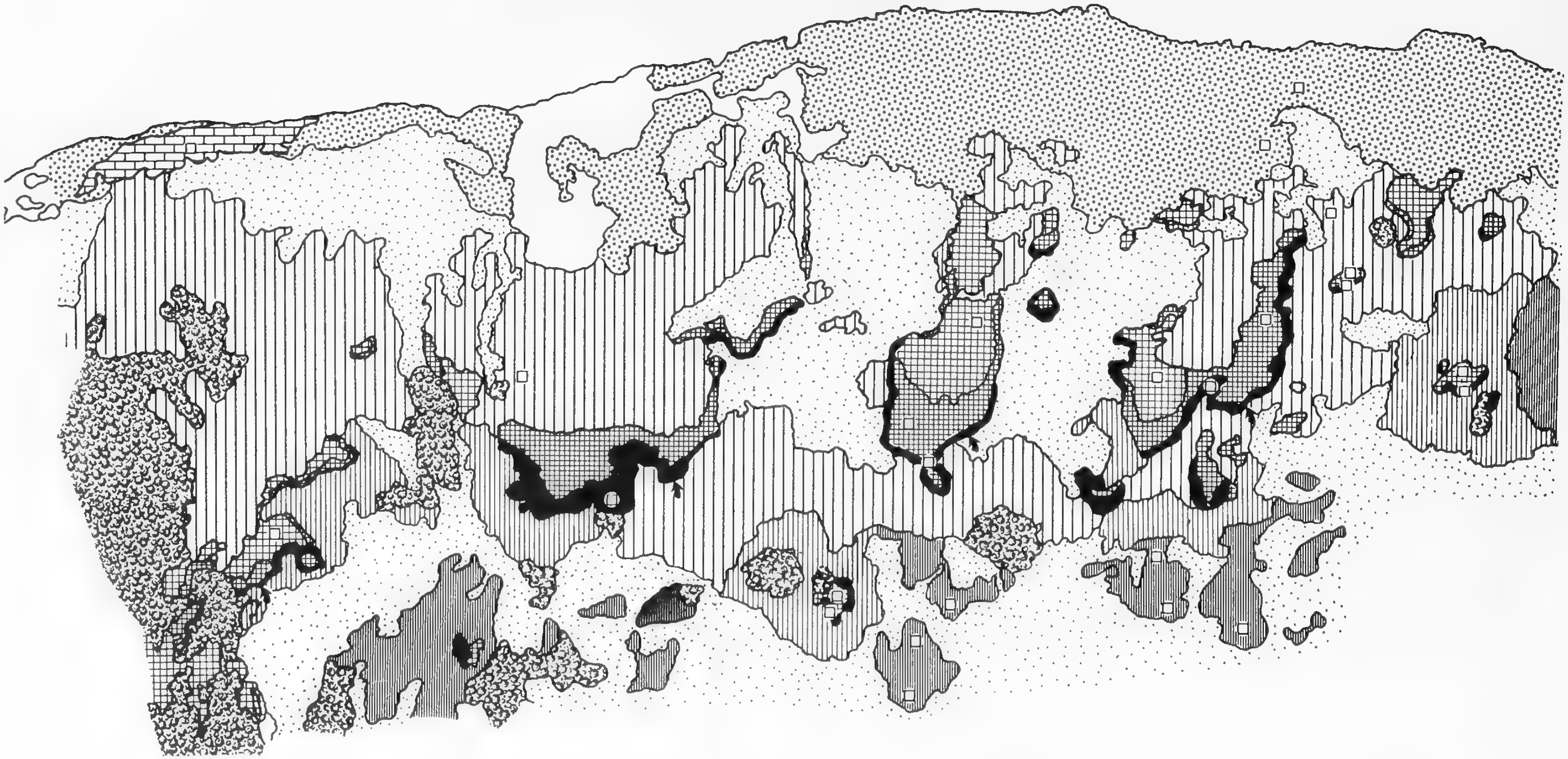


Fig. 4. Eastern part of the Boiler Bay algal ridge (see figure 2), showing zone positions and the locations of quadrats. This diagram has been simplified from the detailed maps of Adey, 1974. Legend as in figure 3.

Fig. 5. Reference reef showing algal ridge zone locations and water sampling sites–. See figure 11 for longitudinal (AA') and effluent (BB') channel sections. B'B" is the boundary of the water mass treated, as determined by float bottles. The arrows on BB' indicate the direction of current flow.

Zones 1-3 as figs. 3 & 4.

Diploria spp.

Porites astreoides

Porites porites

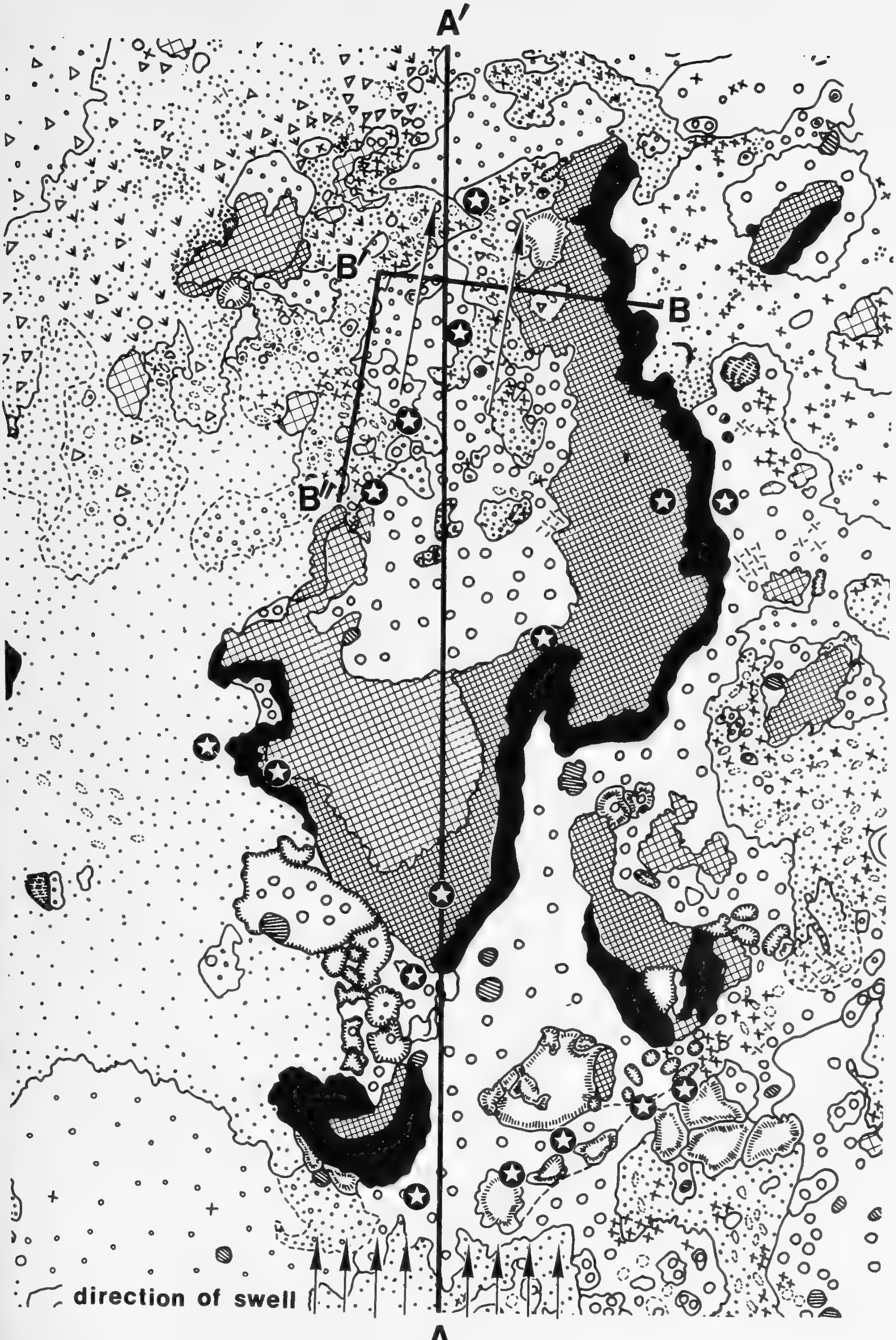
Sideastrea siderea

Carbonate blocks

Algal nodules

Terrigenous stones

Thalassia



A′
B′
B
B″
direction of swell
A

Fig. 6B. Mean wet standing crop as a function of zone. Algae with carbonate skeletons (Jania, Halimeda, Amphiroa and Penicillis) are shown separately in terms of organic biomass and skeletal carbonate. Species number and the number of quadrats taken per zone are indicated.

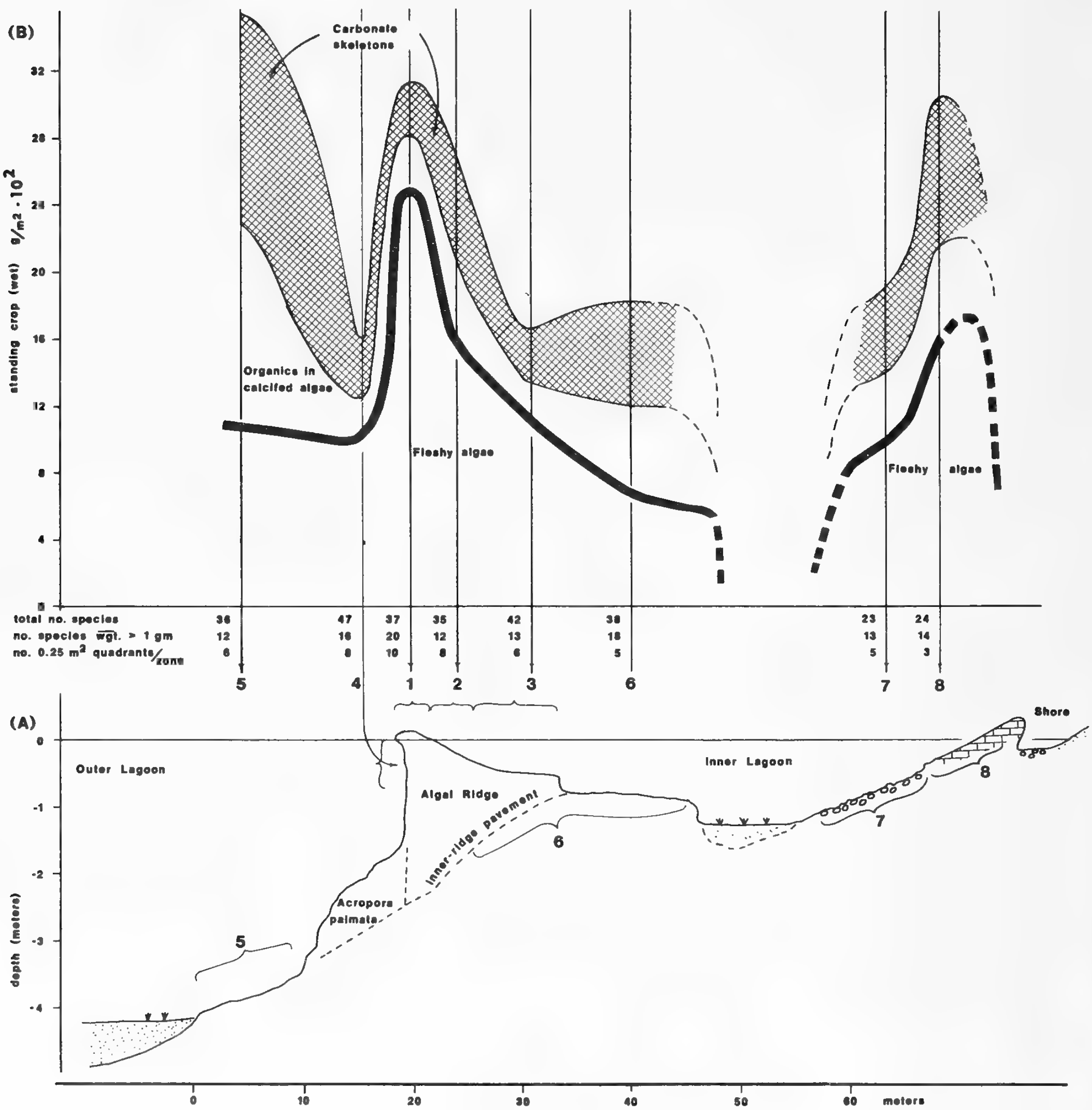


Fig. 6A. Generalized bathymetric transect from the shore across the Boiler Bay algal ridge to the outer lagoon, showing the depths and positions of the algal zones.

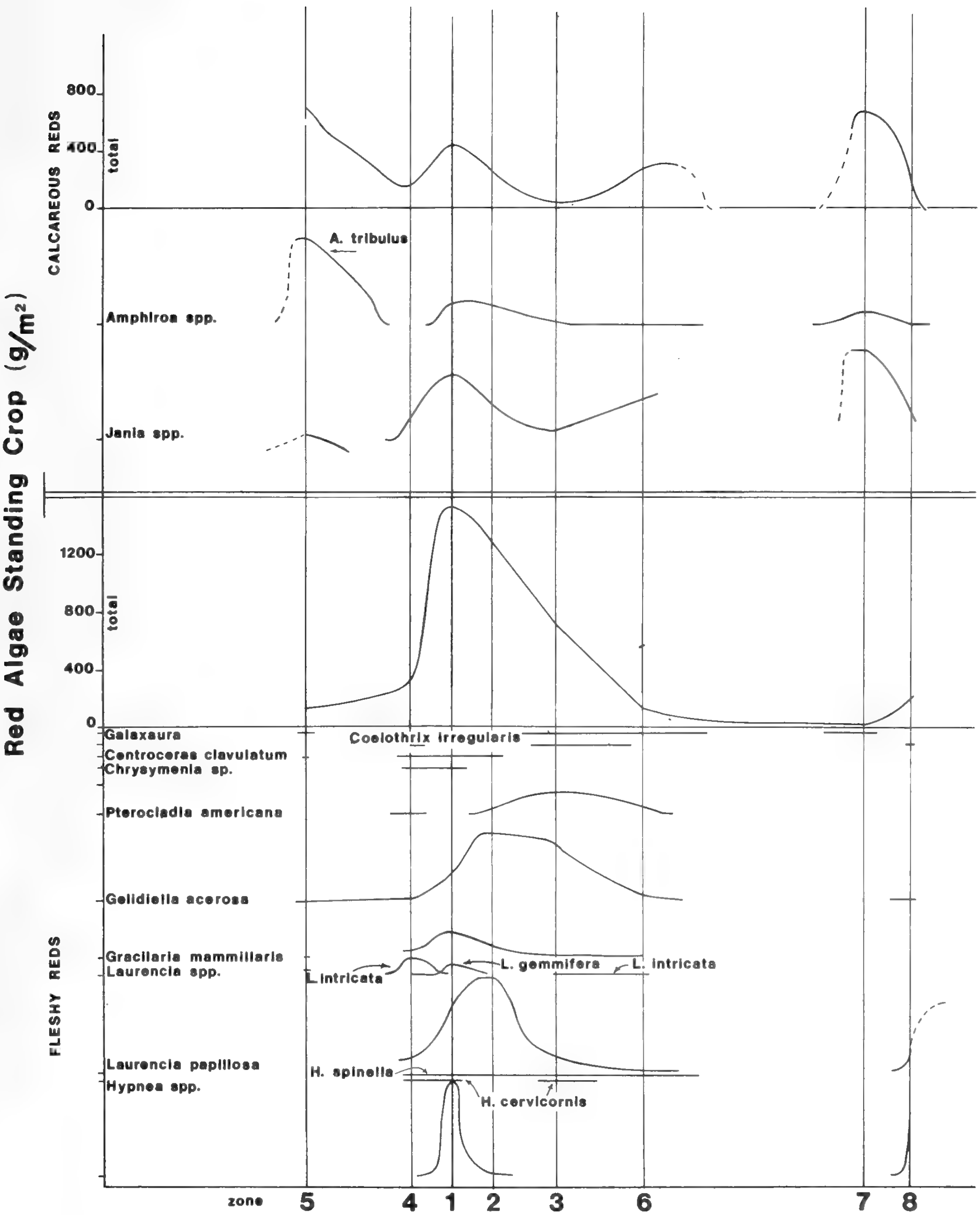


Fig. 7. Distribution and standing crop of the major species of red algae in the algal ridge area of Boiler Bay.

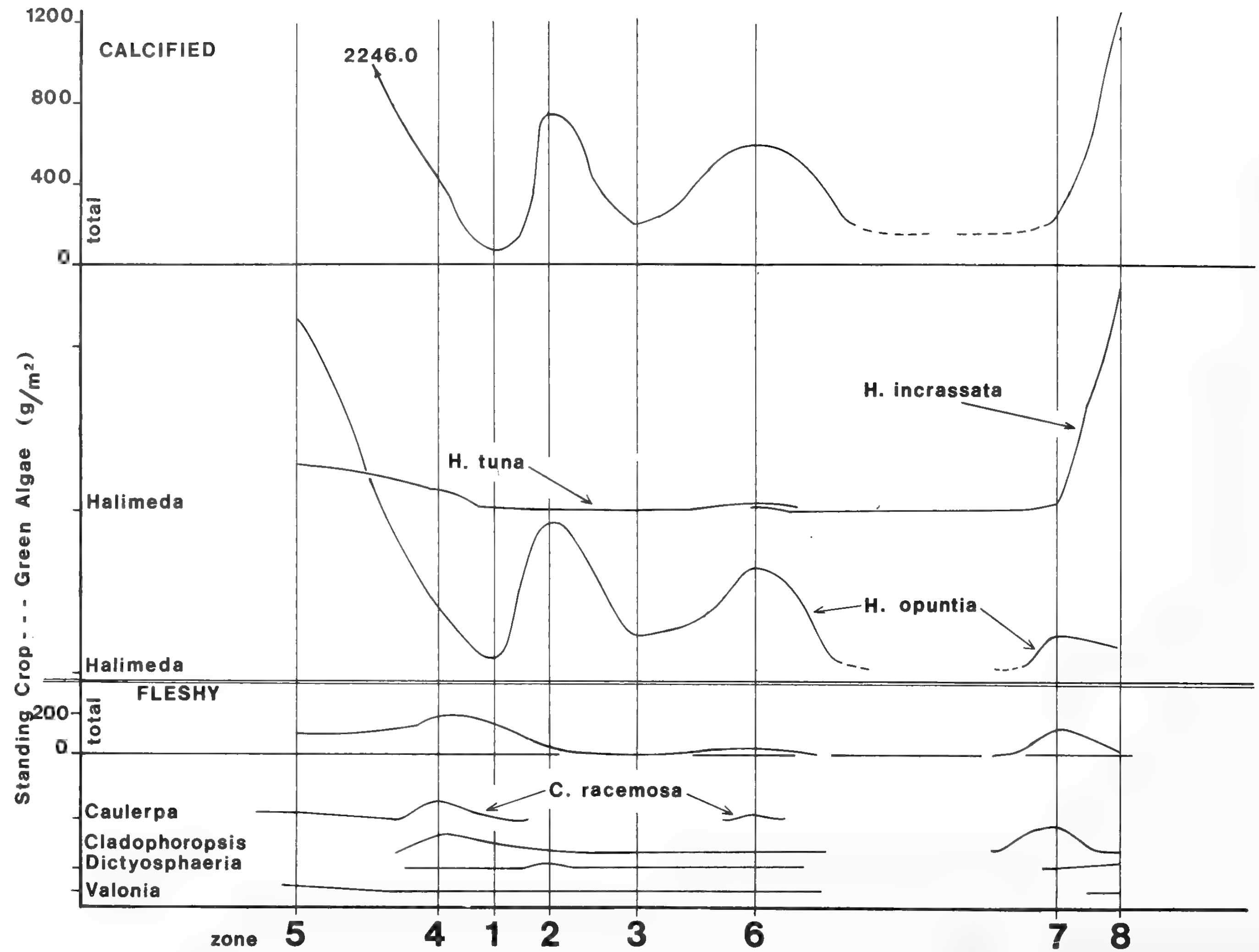


Fig. 8. Distribution and standing crop of the major species of green algae in the algal ridge area of Boiler Bay.

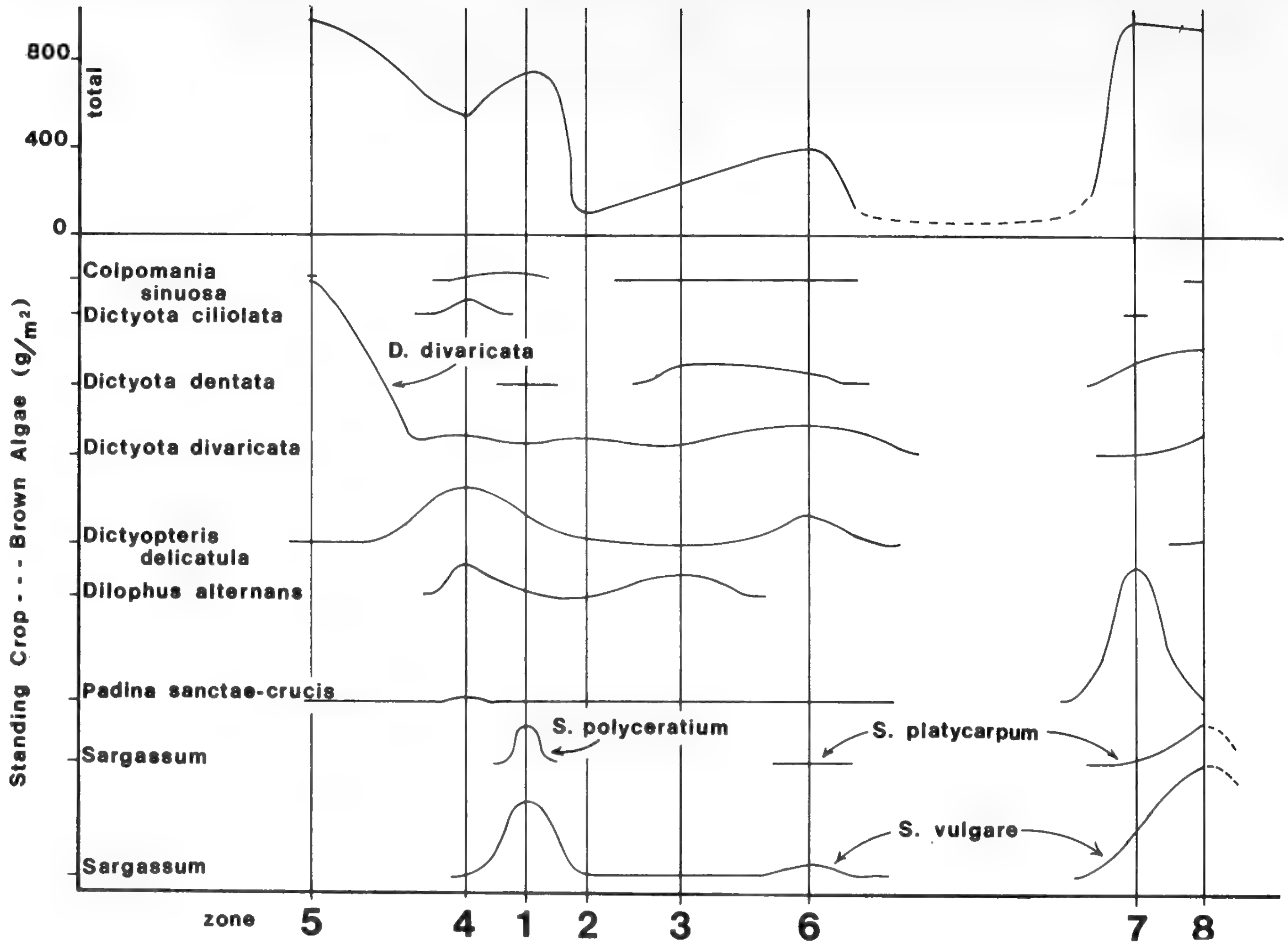


Fig. 9. Distribution and standing crop of the major species of brown algae in the algal ridge area of Boiler Bay.

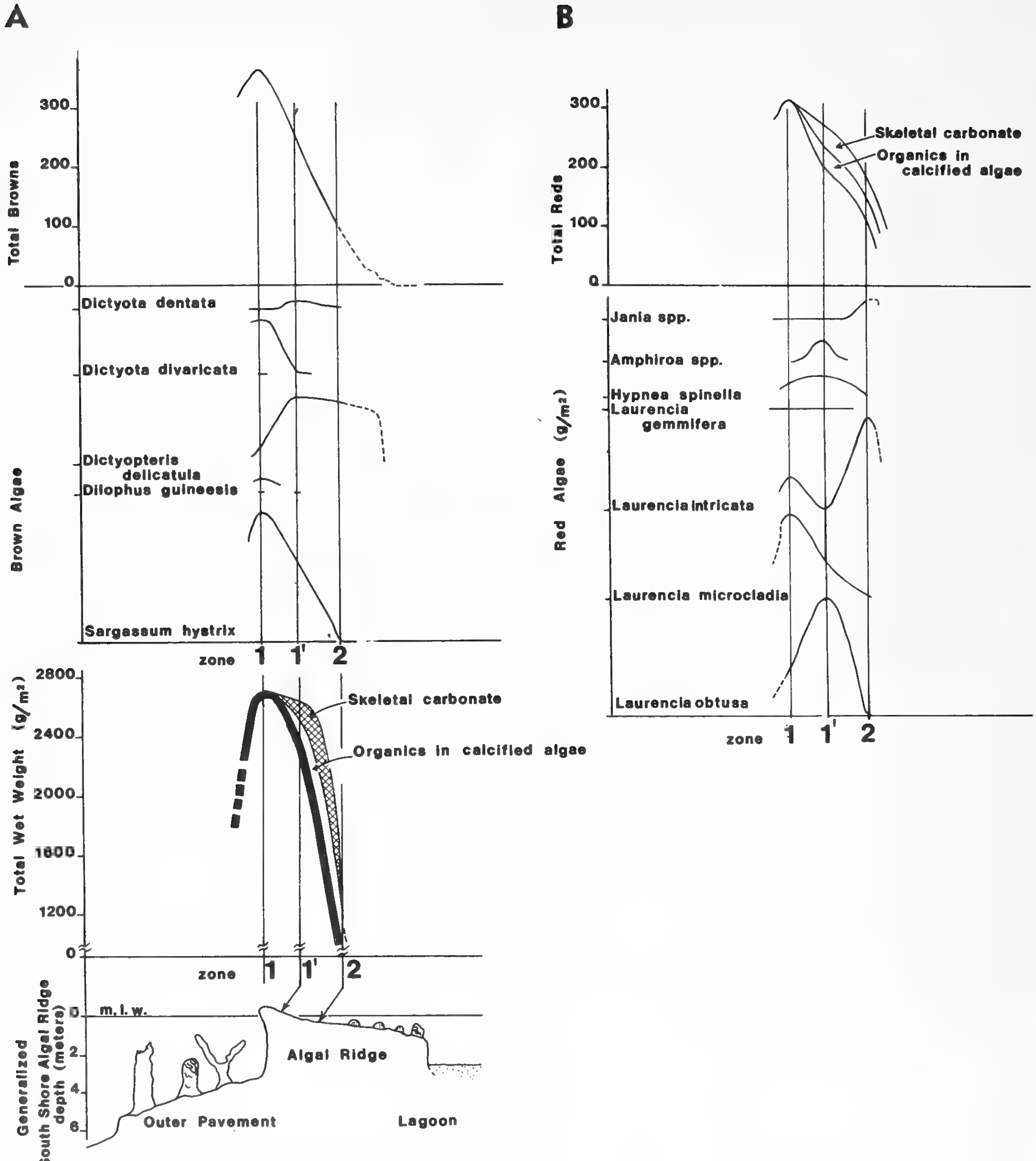
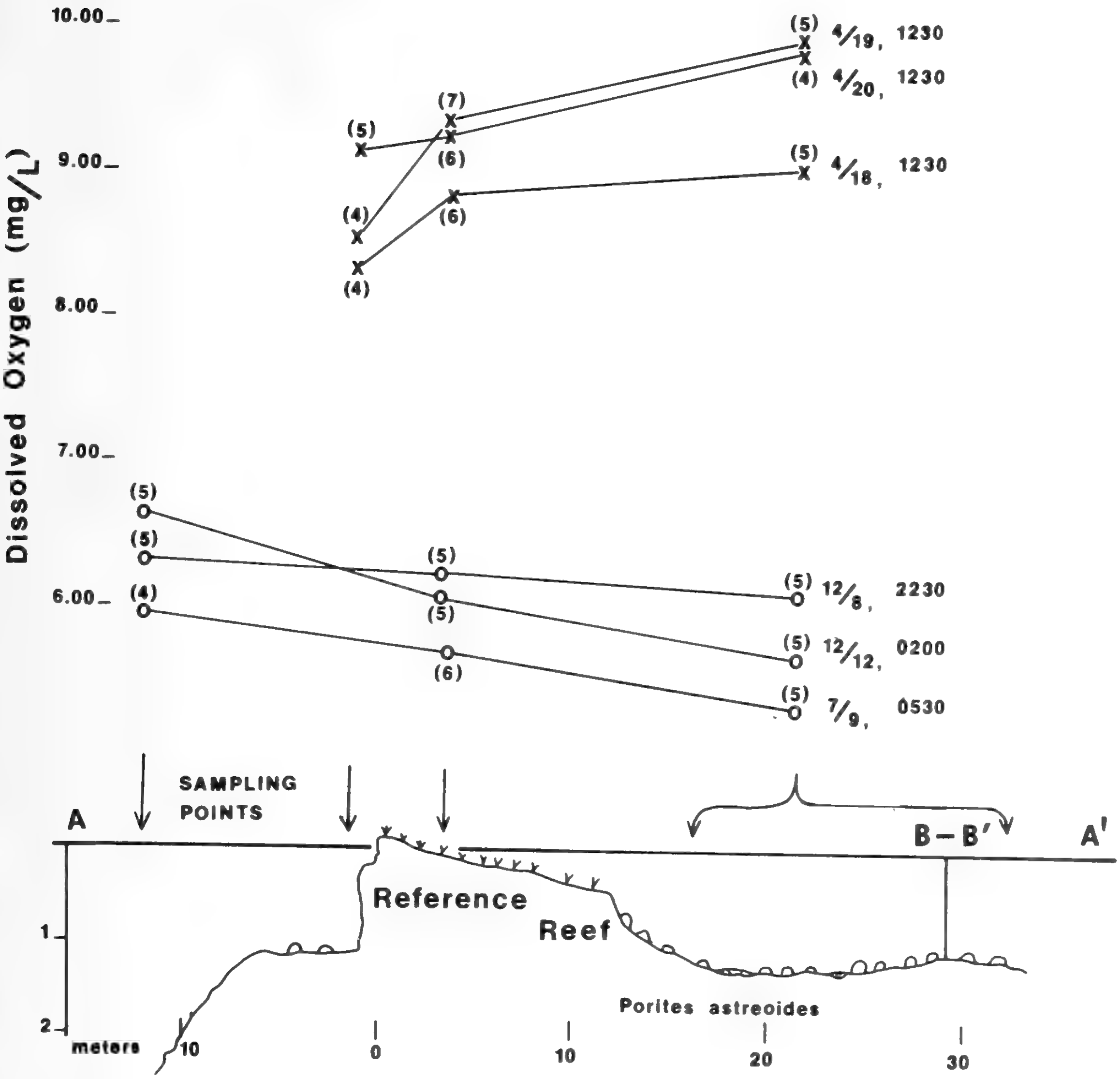


Fig. 10. Distribution and standing crop of fleshy algae on several of the high algal ridges on southeastern St. Croix (see Table 2). 1.6 g of Halimeda opuntia was found in zone 2 of Beach ridge and this is not shown in the diagram.

A - Brown algae
B - Red algae

Fig. 11. Day (x) and night (o) change of dissolved oxygen concentration across Reference Reef. See figure 5 for the location of sections AA' and BB'. (5) indicates the number of water samples. Date and time of sampling is indicated at the right.



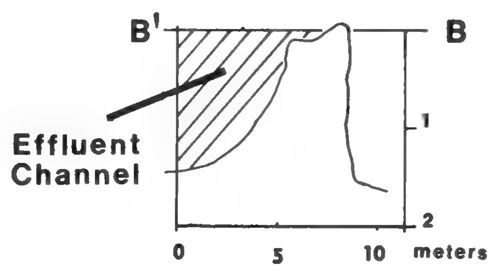


Fig. 12. Standing crops of algae at Waikiki Beach, November 1967. The numbers under the somewhat arbitrary zone breakdown at the bottom of the diagram refer to: (no. spp.) total number of species collected, (sp. > 1 g) number of species with a standing crop > 1 g/.25m², (no. quad.) equivalent number of 0.25 m² quadrats.

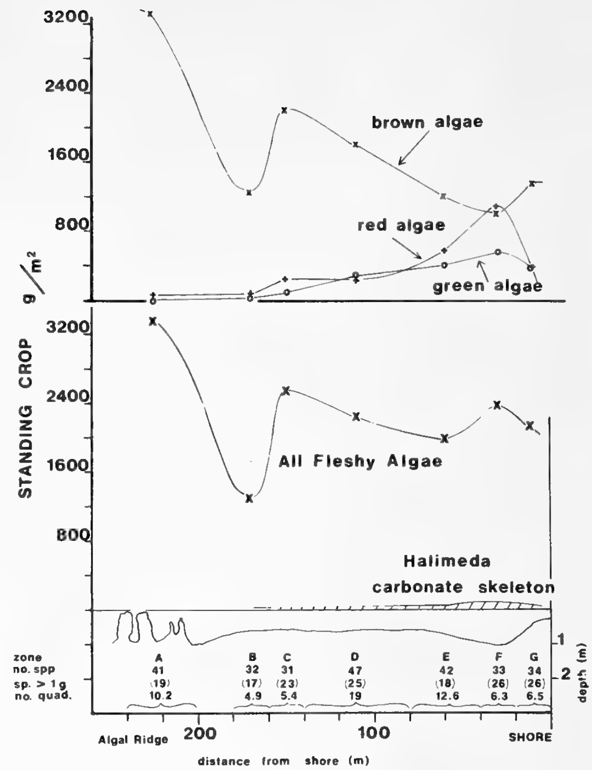


Fig. 13.

Algal standing crop as a function of ease of fish grazing (per zone). x - fleshy and filamentous algae, o - algae with carbonate skeletons (<u>Jania</u>, <u>Halimeda</u>, <u>Amphiroa</u>, <u>Penicillis</u>).

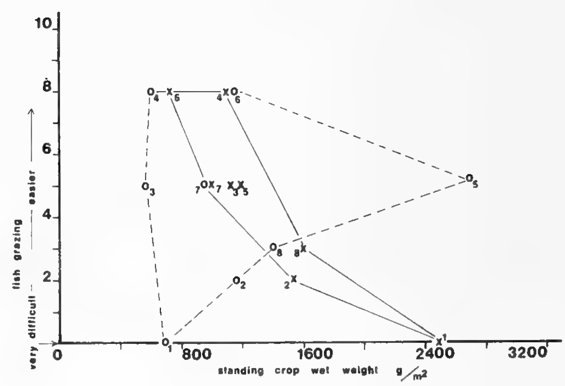


Fig. 14.

Total number of species found/zone (in quadrats) as a function of the number of quadrats taken. x - Boiler Bay, o - Waikiki data (Doty, 1969) converted to 0.25 m² quadrats. Zero was used as a theoretical data point.

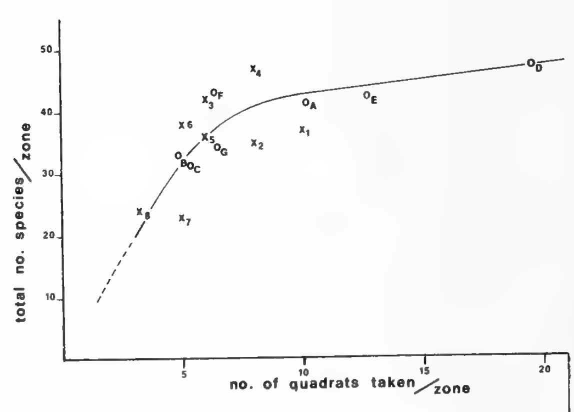
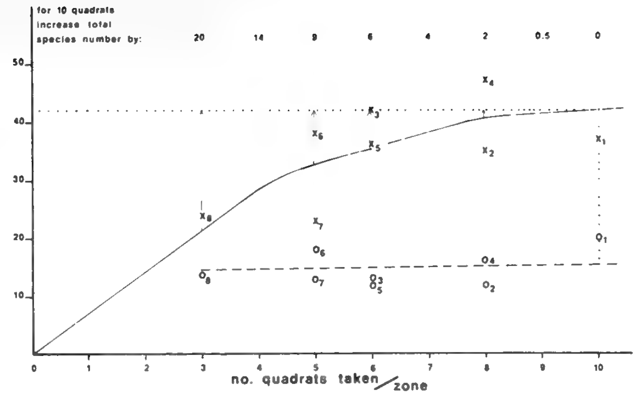


Fig. 15.

Number of species per zone, (x) total and (o) > 1 g/.25m^2, as a function of quadrat number (area collected or collecting pressure) in Boiler Bay. The correction factor is derived as shown (arrow) to adjust all zones to a collection pressure of 10 quadrats.



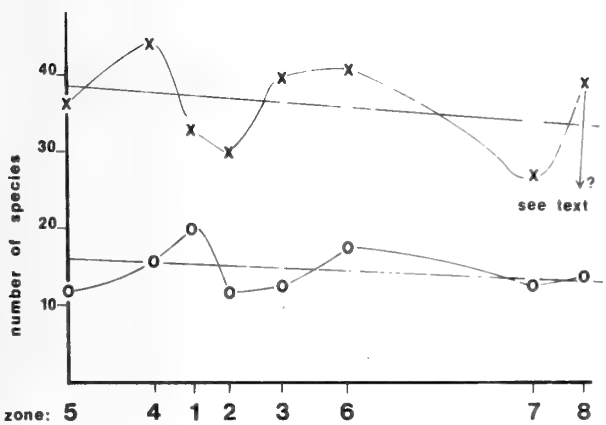


Fig. 16.

(X) total number of species corrected to 10 quadrats (after Fig. 15), and (0) species with standing crops (wet) of 1 g/0.25m^2, as a function of zone on the Boiler Bay ridge (see Fig. 6).

Fig. 17.

Deviation of total species number from the mean (corrected to 10 quadrats) as a function of ease of fish grazing.

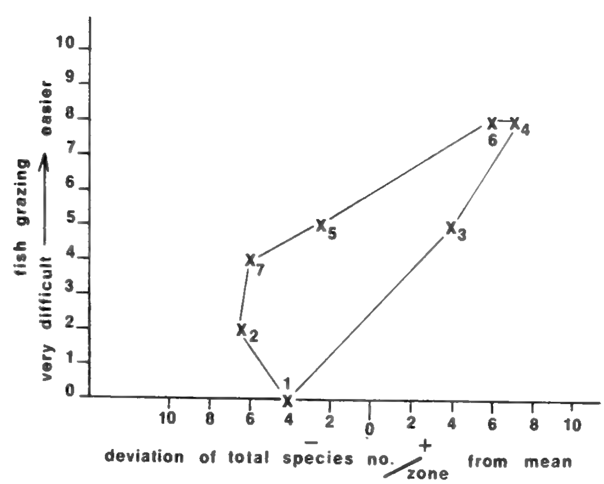


Table 1. List of species, frequency of occurrence in quadrats, and wet standing crop (g/.25m^2), Boiler Bay algal ridge. Weights less than 1 gram indicated by notation "tr". Plants occurring as single small specimens are not listed but appear in species number in figure 12.

Zone and quadrat →	1A	1B	1C	1D	1E
Caulerpa racemosa	24.7				4.4
Cladophoropsis membranacea	19.4			88.7	
Dictyosphaeria cavernosa	5.4				
Halimeda incrassata					
Halimeda opuntia				2.0	24.5
Halimeda tuna					
Penicillis capitatus					
Udotea spp.					
Valonia spp.	3.4				
Colpomenia sinuosa	8.5	10.8	7.6	9.6	3.5
Dictyota ciliolata					
Dictyota dentata				tr	
Dictyota divaricata				139.5	
Dictyopteris delicatula	82.2	tr		tr	15.9
Dilophus alternans		39.0			15.9
Padina sanctae-crucis	tr	2.0	16.2	21.5	1.5
Sargassum vulgare	507.3		83.4	107.9	
Sargassum platycarpum					
Sargassum polyceratium		369.6			4.6
Amphiroa spp.	tr	tr	tr	tr	tr
Centroceras clavulatum				tr	
Chrysymenia sp.					13.0
Coelothrix irregularis					
Galaxaura spp.					
Gelidiella acerosa					19.6
Gracilaria mammillaris	16.3	tr	200.2	40.8	77.3
Hypnea cervicornis	tr				
Hypnea musciformis	160.0	349.0	90.6	124.0	246.8
Hypnea spinella	tr				tr
Jania spp.	222.4	9.7	41.3	181.0	337.4
Laurencia intricata					
Laurencia gemmifera	64.3	43.9		64.0	8.2
Laurencia papillosa	64.3	43.9	128.2	64.0	337.4
Pterocladia americana					

1F	1G	1H	1I	1J	2A	2B	2C	2D	2E
tr									
		3.4	0.8						16.8
					1.7				47.4
36.5	20.5			80.0		475.6	78.9	233.3	72.1
		13.4					tr	tr	tr
							2.1		
tr		6.6						5.7	
tr			10.0						
							94.3	tr	
tr	41.0	tr	94.6	85.0	17.7	3.1	7.5		
						tr			
tr		0.8			tr	tr		0.5	
		2.3	158.8				3.7		1.0
34.0									
tr	tr	267.1	69.0	tr			44.5	238.8	tr
			4.1						
									tr
187.4	68.3				20.1	19.5	185.0	295.8	
70.6		5.2			1.5	34.2	20.4	1.4	
490.5	96.0	13.0	67.3				8.2	2.3	
tr	tr	tr					tr		
28.8	31.6	273.8	tr	tr	104.5	13.6			164.0
tr		tr	tr	tr	tr		tr	tr	
					tr	tr		tr	tr
165.2		183.0	113.5	34.7	147.3	156.8	164.8	223.4	400.1
							36.7		2.5

TABLE 1 (CONT.)	2F	2G	2H	3A	3B	3C
Caulerpa racemosa						
Cladophoropsis membranacea						
Dictyosphaeria cavernosa						
Halimeda incrassata						
Halimeda opuntia	54.7	35.0	554.6	187.8	59.0	133.5
Halimeda tuna				2.9	tr	
Penicillis capitatus						
Udotea spp.						
Valonia spp.	1.2				4.4	0.3
Colpomenia sinuosa						
Dictyota ciliolata						
Dictyota dentata						
Dictyota divaricata	36.9		16.7		46.5	
Dictyopteris delicatula		7.8	tr	tr		
Dilophus alternans				30.1		59.5
Padina sanctae-crucis						tr
Sargassum vulgare					2.9	
Sargassum platycarpum						
Sargassum polyceratium						
Amphiroa spp.	tr	tr	tr			
Centroceras clavulatum		6.1	1.0			
Chrysymenia sp.						
Coelothrix irregularis		6.5		4.3		
Galaxaura spp.						
Gelidiella acerosa	384.8	33.8		214.8	166.6	165.3
Gracilaria mammillaris	70.0	31.2	6.3	5.9	14.3	2.5
Hypnea cervicornis				5.3		
Hypnea musciformis			1.0			
Hypnea spinella	31.2					
Jania spp.	192.4	tr	tr	21.3		69.0
Laurencia intricata	tr		tr			
Laurencia gemmifera			tr		tr	
Laurencia papillosa	40.4	115.0	85.6	43.5	106.4	10.0
Pterocladia americana		25.0	35.3	14.4	190.2	7.5

3D	3E	3F	4A	4B	4C	4D	4E	4F	4G
						136.2		24.0	
	tr			4.0					
		tr	3.0					tr	
	91.3(?)								
102.5	188.8	26.4	tr	17.8	177.6				
tr			28.0		tr		67.0	6.3	90.7
1.6									
4.3	13.0								
			tr		0.7	tr			tr
		tr	18.8	1.9		0.9	tr		
			tr	tr	60.6	10.9			
131.0									
	46.5		110.3	58.1					
			109.1	78.4		118.2	3.4	25.5	172.5
		59.5					141.4	34.2	7.3
		0.6	3.2	1.5	2.1	tr	tr	tr	
	5.1		3.2						
	18.8								
			2.6		3.9				
				0.3		17.3		3.5	4.2
		tr			24.6			tr	
16.9		5.4							
tr	43.0	3.0		1.2			tr	3.5	17.6
12.7	2.1		54.6	4.0	1.1	14.8	8.6	3.2	
					11.1	2.1	tr	tr	15.6
		2.5							
		7.6	49.3	58.0	17.0	14.0	69.6	46.7	21.3
		tr		40.5	tr	4.7	tr	100.0	tr
				tr			tr	tr	.
		19.1	98.4		38.0		77.3	tr	tr
	2.8		1.1						

TABLE 1 (CONT.)	4H	5A	5B	6A	6B	6D	7A
Caulerpa racemosa	9.0		26.3			13.6	
Cladophoropsis membranacea					2.5		
Dictyosphaeria cavernosa			2.0		2.3		3.4
Halimeda incrassata			1.8	14.1			
Halimeda opuntia	496.0	318.2	61.6	65.2	224.3	107.6	70.0
Halimeda tuna						46.7	
Penicillis capitatus		8.4	5.2	15.1			2.0
Udotea spp.		9.1	20.0	1.4			
Valonia spp.				1.7		tr	
Colpomenia sinuosa		1.0			1.6		
Dictyota ciliolata							
Dictyota dentata		234.7	286.3		4.5		
Dictyota divaricata		tr		145.7		31.0	
Dictyopteris delicatula	tr				77.4		84.3
Dilophus alternans	99.4	tr	tr				
Padina sanctae-crucis		3.1	3.7				5.2
Sargassum vulgare		tr		14.8	26.2		30.1
Sargassum platycarpum		22.2	4.6	tr			
Sargassum polyceratium							
Amphiroa spp.						7.9	
Centroceras clavulatum							
Chrysymenia sp.	0.3						
Coelothrix irregularis							
Galaxaura spp.		14.2	25.5	14.3			2.8
Gelidiella acerosa		107.3	162.9			19.2	11.2
Gracilaria mammillaris		1.2	1.3				
Hypnea cervicornis							
Hypnea musciformis							
Hypnea spinella	2.3						
Jania spp.	78.0	73.4	59.6	1.6	72.0		268.0
Laurencia intricata	83.0					tr	
Laurencia gemmifera	tr						
Laurencia papillosa	tr				1.0	16.0	
Pterocladia americana		tr	tr			6.8	

7B	9A	9B	9C	9D	9E	10A	10B	10C	12A
	25.4	90.5	41.3			tr		2.2	
			2.3			0.8	0.6	10.1	
	6.0	5.4	tr	11.6				836.9	
229.6	28.4		109.8	86.1				100.3	238.7
2.5	13.7			5.3		2.4		15.3	
9.3				19.3					
2.5							0.6	3.8	tr
						1.0			
		tr			1.1				
75.1	5.4		42.4	85.4	tr	124.5	0.7		1.0
		7.1						63.0	199.0
						4.3			2.5
	3.9	529.1	2.4		233.4	8.3			
5.3		95.5	137.0	60.2		381.7			
1.7	7.2		tr	9.0		130.5			
				104.9			tr		301.9
							2.3		
76.6				8.7					30.0
14.3								0.3	0.5
							331.5		
5.3	300.0	123.9	204.0		121.4	8.9	121.3	11.4	7.4
							119.5		
2.4									

TABLE 1 (CONT.)	12B	12C	12D	12E	12F
Caulerpa racemosa					
Cladophoropsis membranacea					
Dictyosphaeria cavernosa					
Halimeda incrassata			tr	43.1	62.2
Halimeda opuntia	318.0	420.9	632.6	413.5	628.0
Halimeda tuna	2.2	45.8	2.4	158.8	50.7
Penicillis capitatus	tr			2.8	8.6
Udotea spp.			3.8	11.3	1.4
Valonia spp.	6.4		17.8		
Colpomenia sinuosa			0.7		1.4
Dictyota ciliolata					
Dictyota dentata					
Dictyota divaricata	270.0	306.0	69.2	219.0	232.2
Dictyopteris delicatula	6.8	1.9	5.3	8.2	2.3
Dilophus alternans					
Padina sanctae-crucis				0.4	
Sargassum vulgare			3.0		
Sargassum platycarpum					
Sargassum polyceratium					
Amphiroa spp.	157.4	211.1	252.2		
Centroceras clavulatum					
Chrysymenia sp.					
Coelothrix irregularis			0.9		
Galaxaura spp.	44.8		14.2	13.7	2.2
Gelidiella acerosa	0.8	3.7	4.0	15.4	4.7
Gracilaria mammillaris				0.3	
Hypnea cervicornis	tr				
Hypnea musciformis					
Hypnea spinella					
Jania spp.				38.3	40.2
Laurencia intricata	0.8	0.3	0.6		tr
Laurencia gemmifera					
Laurencia papillosa					
Pterocladia americana					

Table 2. South Shore Algal Ridges.

	Isaac 1	Beach 1	Robin Inner 1	Robin Outer 1	Isaac 2	Beach 2	Isaac 3
Caulerpa racemosa							
Cladophoropsis membranaceae							
Dictyosphaeria cavernosa							
Halimeda incrassata							
Halimeda opuntia						1.6	
Halimeda tuna							
Penicillis capitatus							
Udotea spp.							
Valonia spp.							
Colpomenia sinuosa							
Dictyota ciliolata							
Dictyota dentata	tr				22.8		1.3
Dictyota divaricata		376.5				6.4	
Dictyopteris delicatula	71.6	44.9		1.5	tr	122.6	101.5
Dilophus alternans			44.4	47.9			
Padina sanctae-crucis							
Sargassum vulgare			31.7	843.0	290.7		
Sargassum platycarpum							
Sargassum polyceratium							
Amphiroa spp.						137.1	
Centroceras clavulatum						4.5	
Chrysymenia sp.							
Coelothrix irregularis							
Galaxaura spp.							
Gelidiella acerosa							
Gracilaria mammillaris							
Hypnea cervicornis							
Hypnea musciformis							
Hypnea spinella	49.0		58.2		60.0	16.1	3.0
Jania spp.						tr	31.6
Laurencia intricata		217.9					156.6
Laurencia gemmifera			tr		tr		
Laurencia papillosa							
Laurencia microcladia	295.0	17.3	240.9	15.4	129.5		4.4
Laurencia obtusa	224.0	tr	82.6	9.3	113.0		287.1

231-339 O - '77 - 8

Table 3. Productivity of Reference Reef derived from upstream-downstream analysis of oxygen concentration (see figures 5, 11). Oxygen determined by the Winkler method.

Date	Time	Δ O_2 conc (+ mgO_2/L)	O_2 produced ($mgO_2/m^2/hr$)	O_2 produced ($gO_2/m^2/12$ hr)	C produced ($gC/m^2/12$ hr)
Apr. 18, '73	1230	0.88	7.56×10^3	90.7	27.2
Apr. 19, '73	1230	1.36	14.26×10^3	171.1	51.3
Apr. 20, '73	1230	0.69	5.93×10^3	71.2	21.3
			MEAN NET PRODUCED, DAYTIME		33.3

Date	Time	Δ O_2 conc (- mgO_2/L)	O_2 consumed ($mgO_2/m^2/hr$)	O_2 consumed ($gO_2/m^2/12$ hr)	C consumed ($gC/m^2/12$ hr)
July 9,'73	0530	0.597	5.12×10^3	61.44	18.43
Dec. 8, '73	2230	0.197	1.66×10^3	19.92	5.98
Dec. 12, '73	0200	0.883	2.93×10^3	35.16	10.55
			MEAN CONSUMED NIGHTTIME		11.7 gC/m^2
			NET PRODUCTION (24 hr)		21.6 gC/m^2
			GROSS PRODUCTION		45.0 gC/m^2

Table 4. (opposite page)

Productivity of Reference reef determined from small samples in laboratory aquaria, using polarographic electrodes. The productivity of the carbonate crusts with their attached fleshy algae was determined. The larger algae were then removed and the productivity of the remaining carbonate crust with its coralline crusts and boring algae was redetermined. *Porites astreoides* occupies approximately 16% of the surface area of the zone 6 in the "bowl" of Reference reef. The productivity of the remaining area of this zone was determined as a ratio of its standing crop to the standing crops found in zones 1, 2 and 3.

Table 4.

Collection Site		Including fleshy algae			Fleshy algae removed		
		prod.	resp.	gross	prod.	resp.	gross
Zones 1 & 2 Landing reef	$gO_2/m^2/hr$	5.9	-4.6	10.5	2.3	-2.2	4.5
	$gC/m^2/hr$	1.8	-1.4	3.2	.69	-.66	1.35
	$gC/m^2/12$ hr	21.6	-16.8	38.4	8.3	7.9	16.2
Zones 1 & 2 Stick reef	$gO_2/m^2/hr$	4.4	-3.7	8.1	2.3	-2.2	4.5
	$gC/m^2/hr$	1.3	-1.1	2.4	.69	-.45	1.14
	$gC/m^2/12$ hr	15.6	-13.2	28.8	8.3	- 5.4	13.7
Zones 1 & 2 Sand reef	$gO_2/m^2/hr$	4.0	-2.3	6.3			
	$gC/m^2/hr$	1.2	-0.69	1.9			
	$gC/m^2/12$ hr	14.4	-8.3	22.8			
Zone 3 Sand reef	$gO_2/m^2/hr$	3.2	-3.2	6.4	.6	-1.2	1.8
	$gC/m^2/hr$	.96	-.96	1.86	.18	-.36	.54
	$gC/m^2/12$ hr	11.52	-11.52	23.04	2.16	-4.32	6.48
Zone 6 *Porites astreoides* only	$gO_2/m^2/hr$	1.7	-1.1	2.8			12.1 $gC/m^2/day$
	$gC/m^2/hr$	.51	-.33	.84			
	$gC/m^2/12$ hr	6.12	-3.96	10.1			

Gross production for zones 1 and 2: 30 $gC/m^2/day$ (mean) x 170.7 m^2 (area zones 1 & 2) = 5121.3 gmC/day

Gross production for zone 3: 23.04 $gC/m^2/day$ (mean) x 62.7 m^2 (area zone 3) = 1444.8 gmC

Gross production for *P. astreoides* in zone 6: 10.1 $gC/m^2/day$ (mean) x 155.6 m^2 (area zone 6) x 16% coverage *P. astreoides* = 251.5

Coral pavement in zone 6: 20.5 $gC/m^2/day$ x 155.6 m^2 x 84% coverage = 2679.0

9497/389 m^2 =

24.5 $gmC/m^2/day$

Table 5. Comparison of the productivity of the algal ridge lobe, Reference reef, with other reef systems.

Source & Area	Gross Productivity $gC/m^2/day$
This Study, Reference reef	24-45
Kanwisher & Wainwright, 1967 Florida, Corals	2.7-10.2
Kohn & Helfrich, 1957 Hawaiian reef community	8.1
Odum & Odum, 1955 reef community	9
Gordon & Kelly Hawaiian reef community	10.8-32.7
Helfrich & Townsley, 1961 Hawaii, Eniwetok, P. Rico Coral Reef	4.9-32

ATOLL RESEARCH BULLETIN
NO. 212

PRELIMINARY OBSERVATIONS ON THE ALGAE, CORALS, AND FISHES INHABITING THE SUNKEN FERRY "FUJIKAWA MARU" IN TRUK LAGOON

by Roy T. Tsuda, Steven S. Amesbury, and Steven C. Moras

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

PRELIMINARY OBSERVATIONS ON THE ALGAE, CORALS, AND FISHES INHABITING THE SUNKEN FERRY "FUJIKAWA MARU" IN TRUK LAGOON[1]

by Roy T. Tsuda,[2] Steven S. Amesbury,[3] and Steven C. Moras[2]

Introduction

Of all the sunken ships in the Truk Lagoon, the armed Japanese aircraft ferry "Fujikawa Maru" is by far the center of attraction to SCUBA divers. The ferry, sunk on Feb. 17, 1944 during World War II, is located about 1 km off the southwestern tip of Eten Island and can easily be located since the masts rise above the surface of the water and are clearly visible. The ferry is 439 ft. long and 58 ft. wide with a tonnage of 6,938 (Ronald D. Strong, personal communication). It lies upright on the barren silty bottom in 90 ft. (28.3 m) of water; the main deck is 50 ft. (15.7 m) below the surface of the water.

The "Fujikawa Maru," as well as the other sunken ships in the lagoon, are in essence artificial reefs whose organismal components represent a climax community that has become dominant after a 30 year period. The only (1972) who included the algal species collected from the ferry (Station 13) on June 14, 1970.

---

[1] Contributions No. 67, University of Guam Marine Laboratory.

[2] The Marine Laboratory, University of Guam, P.O. Box EK, Agana, Guam 96910.

[3] Agricultural Experiment Station, University of Guam, P.O. Box EK, Agana Guam 96910.

(Manuscript received June 1975 -- Eds.)

The checklist of the algae, corals, and fishes reported below represent observations made on two dives on March 30, 1975. Although the number of dives is few, it should be pointed out that the sole purpose of the dives was to record the species present. Each of the three authors was responsible for a certain group of organisms - Tsuda (algae), Amesbury (fishes), and Moras (corals). The soft corals which represent a dominant component of the ferry are not included since none of us is familiar with their taxonomy.

Checklist

The algae (21 spp.) are listed under their respective divisions; the corals (26 spp.) and the fishes (34 spp.) are listed under their respective families. The five species of algae collected on June 14, 1970 and not seen in 1975 are also included and are preceded by asterisks.

Algae

Cyanophyta
Microcoleus lyngbyaceus (Kütz.) Crouan

Chlorophyta
Caulerpa ambigua Okamura
Caulerpa brachypus Harvey
Caulerpa filicoides Yamada
**Caulerpa lentillifera* J. Ag.
Caulerpa racemosa (Forskal) J. Ag.
**Dictyosphaeria cavernosa* (Forskal) Boerg.
Halimeda copiosa Goreau & Graham
Halimedo discoidea Decaisne
**Halimeda gigas* Taylor
Halimeda incrassata (Ellis) Lamx.
Halimeda macrophysa Askenasy
Halimeda opuntia (L.) Lamx.
Tydemania expeditionis Weber van Bosse
Udotea geppii Yamada

Phaeophyta
**Dictyopteris repens* (Okamura) Boerg.
Dictyota bartayresii Lamx.
Lobophora variegata (Lamx.) Womersley
Padina jonesii Tsuda
Turbinaria ornata (Turn.) J. Ag.

Rhodophyta
**Champia compressa* Harv.

Corals

Antipathia
Cirrhipathes anguina Dana

Scleractinia

Acroporidae

Acropora delicatula (Brooks)
Astreopora sp.
Montipora erythrae Marenzeller
Montipora verrucosa (Lamarck)

Agariciidae

Pachyseris speciosa (Dana)

Caryophylliidae

Plerogyra sp.

Dendrophylliidae

Tubastraea aurea (Quoy & Gaimard)

Faviidae

Favia favus (Forskål)
Favia speciosa Dana
Favites abdita (Ellis & Solander)
Favites favosa (Ellis & Solander)
Leptastrea immersa Klunzinger
Leptastrea purpurea (Dana)
Platygyra lamellina (Ehrenberg)

Fungiidae

Fungia fungites (Linnaeus)

Mussidae

Lobophyllia corymbosa (Forskål)
Lobophyllia costata (Dana)
Symphyllia nobilis (Dana)
Symphyllia sp.

Pectiniidae

Pectinia laciniata (Milne-Edwards & Haime)

Pocilloporidae

Pocillopora damicornis (Linnaeus)
Pocillopora eydouxi Milne-Edwards & Haime
Seriatopora angulata Klunzinger

Poritidae

Porites lutea Milne-Edwards & Haime
Porites sp.

Fishes

Acanthuridae
Acanthurus nigrofuscus Forskål
Acanthurus nigroris Cuvier & Valenciennes
Ctenochaetus striatus (Quoy & Gaimard)
Naso unicronis (Forskål)
Zebrasoma scopas (Cuvier)
Zebrasoma veliferum (Bloch)

Balistidae
Balistapus undulatus (Mungo Park)

Blenniidae
Meiacanthus atrodorsalis (Gunther)

Chaetodontidae
Centropyge bicolor (Bloch)
Chaetodon auriga Forskål
Chaetodon kleinii Bloch
Heniochus acuminatus (Linnaeus)

Cirrhitidae
Cirrhitus pinnulatus (Bloch & Schneider)
Paracirrhites forsteri (Bloch & Schneider)

Gobiidae
Amblygobius albimaculatus (Ruppell)

Labridae
Cheilinus fasciatus (Bloch)
Epibulus insidiator (Pallas)
Gomphosus varius Lacepede
Halichoeres hoeveni (Bleeker)
Thalassoma lutescens (Lay & Bennett)

Lutjanidae
Caesio caerulaureus Lacepede
Pterocaesio sp.
Scolopsis cancellatus (Cuvier & Valenciennes)

Mullidae
Parupeneus pleurostigma (Bennett)

Pomacentridae
Abudefduf glaucus (Cuvier & Valenciennes)
Chromis caeruleus (Cuvier & Valenciennes)
Chromis dimidiatus (Klunzinger)
Dascyllus aruanus (Linnaeus)
Dascyllus reticulatus (Richardson)

Dascyllus trimaculatus (Ruppell)
Pomacentrus pavo (Bloch)

Scaridae
Scarus sordidus Forskål

Siganidae
Siganus argenteus (Quoy & Gaimard)

Zanclidae
Zanclus cornutus (Linnaeus)

Discussion

A vertical zonation pattern is evident on the masts which rise above the surface. The shallow water *Pocillopora eydouxi* (coral) and *Turbinaria ornata* (brown alga) were only found on the masts at the surface. Clouds of *Pomacentrus pavo* and *Chromis caeruleus* were also observed around the masts.

The substratum on the deck is composed of fine and coarse fragments of *Halimeda* which have accumulated over the past 30 years. Although corals cannot settle here, this substratum provides an ideal habitat for the massive holdfasts of the green algae *Udotea geppii* and *Halimeda incrassata*.

The bulkhead provides an ideal habitat for mats of the flabellate form of *Tydemania expeditionis*, *Caulerpa filicoides*, and the straggly *Halimeda copiosa*. *Lobophora variegata* encrusts the bulkhead of the upper deck. *Lobophyllia costata* and *Symphyllia* sp. were the dominant corals on the various superstructures of the ferry with some colonies reaching 40 cm in diameter. The pomacentrids were the most numerous of the resident fish species. Besides those pomacentrids observed around the masts, schools of *Dascyllus* species were seen around the coral growths of the ferry. Acanthurids were quite common though never in large schools.

Except for the epiphytic *Champia compressa* on *Halimeda*, members of the red algae were conspicuously absent. Likewise, populations of chaetodontids were sparse. Few piscivorous fishes were observed on the ferry. Considerably more were seen on another ship, a sunken destroyer off Dublon, which was resting on a coral substrate which supported a large fish fauna of its own. Schools of roving fishes (*Caesio caerulaureus* and *Pterocaesio* sp., and the rabbitfish *Siganus argenteus*) were also very abundant, but this is probably quite variable over time.

The more than sixty sunken ships (Stewart, 1972) in the Truk lagoon present a unique opportunity for the study of reef community structure. The time available for colonization of the artificial

reefs is known for each of the ships. The variation in size of the ships and their position with respect to water depth, substrate type, distance from one another, and distance from natural reef areas provide a series of natural experiments on the effect of a variety of environmental factors on reef community development. It is hoped that this checklist will serve as a start for further studies in this unique natural laboratory which is protected by local law.

Literature Cited

Stewart, W. H. 1972. Historical and geographic tourist map of the ghost fleet in the Truk Lagoon, Eastern Caroline Islands, Pacific Ocean, with notes on the ocean and World War II. Trust Territory of the Pacific Islands, Publications and Printing Division.

Tsuda, R. T. 1972. Some marine benthic algae from Truk and Kuop, Caroline Islands. Atoll Res. Bull. 155: 1-10.

ATOLL RESEARCH BULLETIN
NO. 213

CHEMISTRY OF FRESHWATER POOLS ON ALDABRA

by A. Donaldson and B. A. Whitton

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

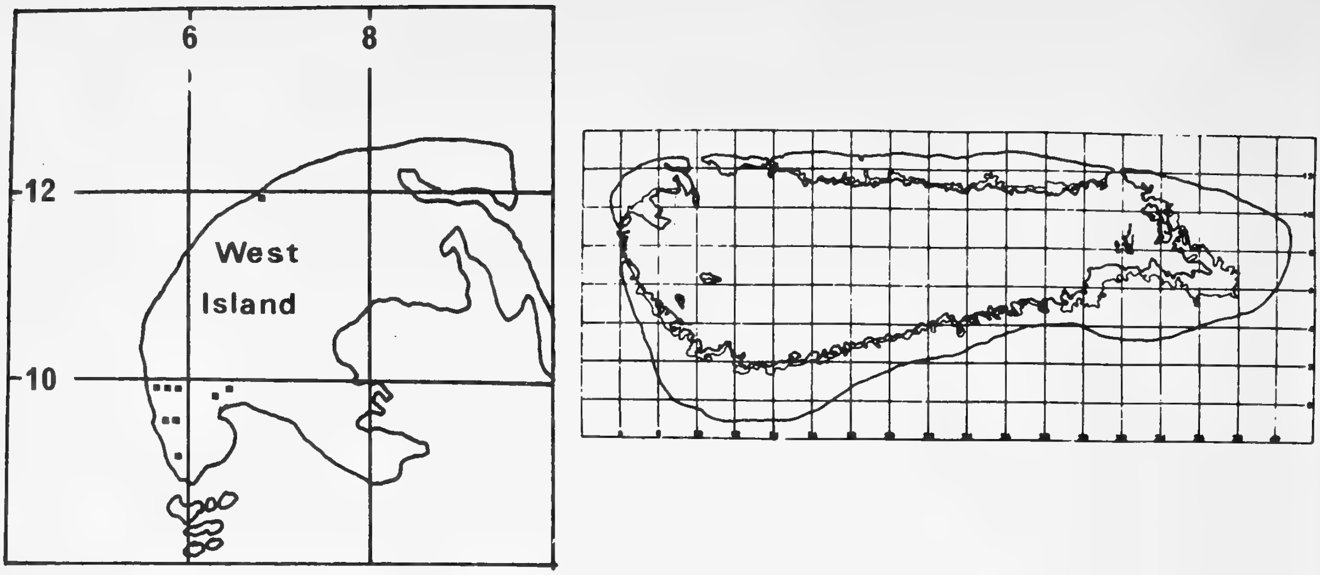
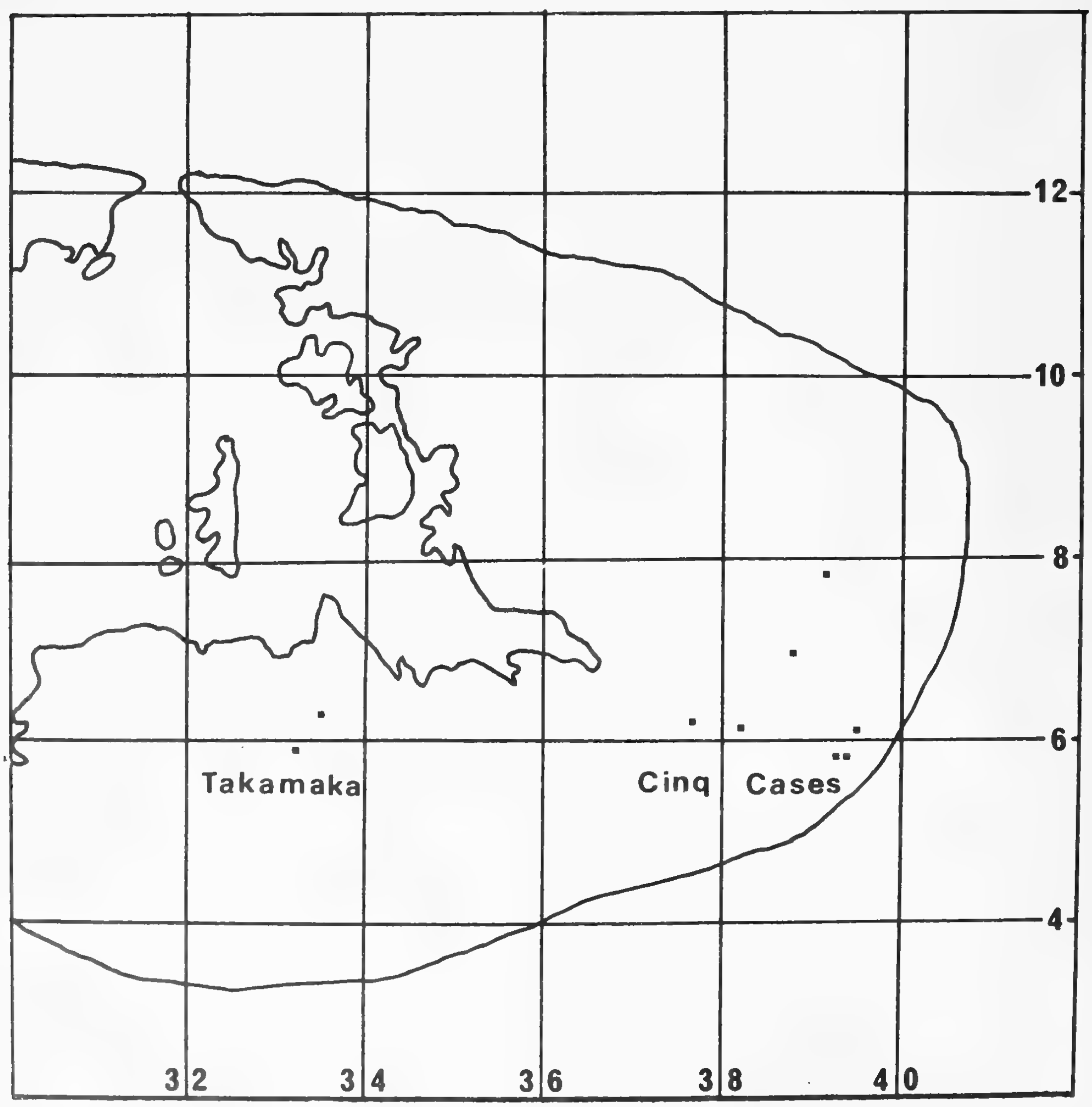


Fig. 1. Aldabra, showing location of 20 pools studied.



CHEMISTRY OF FRESHWATER POOLS ON ALDABRA

by A. Donaldson and B. A. Whitton [1]

ABSTRACT

An account is given for 20 freshwater pools on Aldabra of some of their physical and chemical parameters likely to be of particular biological significance. The majority of these pools were permanent throughout the wet season studied, but dry for the remainder of the year. They were in general characterized by moderate to high levels of both phosphate and ammonia. Some pools were chosen for more detailed study of changes through both the whole season and individual days. Levels of Na, K, Mg, Ca, Cl tended to increase through the part of the season studied, whereas those of phosphate and ammonia showed no such clear trend. Diurnal cycles were evident for various parameters such as level of dissolved oxygen, and in at least one case Ca and possibly also Mg. It is suggested that the algae *Oedogonium* and *Plectonema gloeophilum* may play a major role in bringing about such diurnal changes in Ca.

INTRODUCTION

Although freshwaters usually cover only a small fraction of the total surface of atolls, they do provide a habitat of particular ecological interest. Further, they are probably the easiest habitat for which it is possible to obtain accurate data on a wide range of chemical parameters of biological significance. Apart from comments on salinity, there are apparently no reports in the literature on the

---

[1] Department of Botany, University of Durham, Durham, England
Manuscript received 8 July 1975 -- Eds.)

chemistry of such pools. The following account deals with representative freshwater pools on Aldabra during the wet season of 1972/1973.

The four islands (Fig. 1) of the Aldabra group (9° 24′S, 46° 20′E) are formed of coral reefs elevated 5 to 10 m above present sea-level. They are situated in a relatively dry part of the southwest Indian Ocean, with a mean annual rainfall of 1070 mm (see both Stoddart, 1971a and Stoddart and Mole, in press). Further background information on their geology, geography and ecology is given in the volume edited by Westoll and Stoddart (1971), while Braithwaite *et al.* (1973) have provided a detailed account of the islands' geological history. Baker (1963) commented briefly on the phosphate content of rocks and soils. He reported that guano is rare, but that it does occur in small quantities on West Island. Small pockets of residual soil also occur locally on this island, and their composition ranges from 5.2 - 12.6% P. Pale yellowish brown soils in the Cinq Cases region are low in phosphate, rarely exceeding 0.87% P. All but two of the pools reported in the present survey are from either West Island or the Cinq Cases region. Baker also described a small area of phosphatic rocks containing between 15.7% and 19% P, but these could not be included in our study since freshwater pools were absent in their vicinity.

McKenzie (1971) recognized five main categories of terrestrial aquatic niche (for Entomostraca) on Aldabra: permanent freshwater reservoirs, temporary rainwater rock-holes, brackish pools, tide controlled pools, highly saline pools not obviously tide controlled. The salinity range for permanent freshwater reservoirs fell between 0.6 and 9.4‰ and that for temporary rockholes between 0.1 and 10.5 ‰. Our study deals largely with sites which fall into McKenzie's category of temporary rainwater rockholes. The pools chosen were however mostly permanent throughout the wet season of 1972/73, though nearly all were dry for the remainder of the year (Table 1). They were all at the lower end of the salinity range.

The account first summarizes data on the chemistry of pool waters (but not muds). It then discusses features of their chemistry which provide clues to the factors influencing the pools which are themselves of importance in influencing organisms associated with the pools. A more detailed account of their algal vegetation is included in another paper following on the present one.

METHODS

Data summarized in Table 1

Grid references. These have been devised as follows. Either the pool itself, or the nearest obvious landmark, was first located on

the reduced lay-down of the June 1960 aerial photographs (D.O.S. (P.M. SEY) Aldabra West, Aldabra East, 1969). The position on these photographs was then related to the two nearest points (such as sites with bench-marks) findable both on the aerial photographs and the outline map of Aldabra which includes both grid lines and bench marks (D.O.S. 304 - series Y852, 1964). Using these marker points, the position of the pool was determined on the outline map, thus giving the grid reference.

Geological stratigraphy. The types of rock were established, by relating the grid reference to the map given by Braithwaite *et al.* (1973), and not by direct observation on the ground.

Vegetational types. The names used are based on those given by Fosberg (1971).

The authors hold a detailed guide to the location of these pools, together with a system of nomenclature for pools on Aldabra. They would be pleased to supply copies to any interested.

Water analyses

Provided that a pool was deep enough, probe measurements and a sample were taken at 0.2 m depth. If they were shallower, then the sample was taken half-way between the surface and the bottom. It was filtered immediately through a No. 2 SINTA funnel into a 250 ml polythene bottle. A No. 2 funnel is quoted by the manufacturers as having a maximum pore diameter of 40-50 µm. Although many algae had one or more dimensions smaller than this, nevertheless the SINTA funnel held back the great bulk of the algal standing crop.

Part of the filtrate was used immediately for analyses with the aid of HACH portable kits, while the remainder was stored in the polythene bottle at $-10^{\circ}C$ apart from the times between collection and return to camp, and during transit to U.K.

1. $O.D._{420nm.}$ Optical density measurements were made only on the stored samples, and are probably the least reliable of the parameters recorded.

2. Temperatures. Use of thermistor incorporated with oxygen probe and/or mercury thermometers.

3. pH. Use of PYE UNICAM portable meter model 293.

4. Dissolved oxygen. Use of Lakelands Instrument Co. portable meter, with Mackereth type electrode.

5-8. Na, K, Mg, Ca were all measured after return to U.K. Analar HCl was added to the samples and measurements made by atomic absorption spectroscopy (PERKIN-ELMER 403). With the possible exception of the lowest K levels, the errors associated with storage may be assumed to be small.

231-339 O - '77 - 9

9. Cl. Use of argentometric titration.

10-12. Orthosphosphate, polyphosphate and organic phosphate. Use of HACH portable kits. Levels below the minimum detectable were recorded only for polyphosphate (0.01 mg l^{-1}p).

The so-called polyphosphate fraction may possibly be heterogeneous, as it is that part which gives the orthophosphate colourimetric reaction only after hydrolysis with H_2SO_4. If any orthophosphate-containing material which passes through the SINTA funnel should not be soluble in the acid provided with the HACH kits (final c. 1.8), then it would be included in the polyphosphate rather than the orthophosphate fraction.

13-15. $(NH_3 + NH_4)$-N, NO_2-N, NO_3-N. Use of HACH portable kits. It seems possible that the values indicated for nitrite and nitrate were underestimates due to interference from other substances in the pools. Urea, for instance, if present, would cause a marked interference. Samples from several sites where it was thought probable that interference would occur were checked by the method of additions and no such interference was in fact found. As it was impractical to carry this out for every analysis, the data summarized here for nitrite and nitrate should be treated with caution.

Representative rock samples were taken from the sides of the pools. Small amounts (c. 0.2 g) were subsequently removed from immediately below the algal layer (epilithic, or endolithic, if latter present), and analyzed for Mg, Ca and inorganic phosphate soluble in cold 25%, HCl.

LOCATION OF POOLS STUDIED AND SAMPLING PROGRAMME

The location of the pools studied is shown in Fig. 1, examples are illustrated in Figs. 2 - 6, and environmental details summarized in Table 1. Total rainfall was exceptionally high during the 1972/73 wet season (1 Dec - 25 May: 1414 mm) and some of the pools listed in Table 1 as permanent through the wet season probably hold water only intermittently during wet seasons with low rainfalls. All the pools studied were free of obvious tidal influence.

The pools were sampled for their water chemistry, and in most cases also for rock samples. For practical reasons it was not possible to adopt for the water chemistry survey a rigorous programme of visits to pools, time of day of sampling, or measurements of all parameters for all samples. A summary of the individual analyses carried out is given in Table 2.

Programme A was used to establish the main features of the pools, and possible correlations between individual ions. This consisted of 54 samples from 19 different pools. Where samples were taken from a single pool on more than one occasion (Table 2), these were in all

cases separated by at least two weeks. In most cases there was about 17 weeks between the first and last sample. Most samples in A were taken between 0800 and 1100 h.

Programme B was used to establish the changes in individual parameters over 24 h. It involved a further 82 samples in addition to those in A. Pools W1, W2, W4, W5, W10 were all studied over full 24 h cycles, while T1 and T2 were studied from early morning to late evening.

In addition to these sampling programmes, individual measurements for temperature, pH and dissolved oxygen were made both on other occasions, in these same pools, and also in other pools. Where results from these are included, this is mentioned specifically.

RESULTS AND DISCUSSION

Individual parameters

Data concerning individual parameters are summarized in Tables 3 and 4, and those on diurnal cycles in Table 5. The relationship between various pairs of ions is shown in Fig. 7, and examples of diurnal cycles in Fig. 8. A wide range of factors may be expected to influence the chemistry of a pool (Fig. 9). The following discussion includes the evidence available for establishing that particular factors are of quantitative significance.

1. Optical density. Water in pools with decaying leaves sometimes appeared brown in colour, this being especially evident if *Casuarina* 'needles' were present. In the present survey, even after storage, the range of values for $O.D._{420\ nm}$ from pools near *Casuarina* was clearly different from pools away from *Casuarina* (0.146 ± 0.055, $n = 9$ *v.* 0.048 ± 0.025, $n = 15$).

2. Temperature. Depth profiles were carried out in the deeper pools on West Island on various dates and various times of day. During the day-time there was usually a slight decrease in temperature with increasing depth, the maximum recorded difference being $3.6^{o}C$ (in W1 with maximum depth of 0.69 m, at 1520 h on 8 March). A very slight increase however sometimes occurred immediately above the surface of the bottom mud (e.g. in W1). At night-time the pools were more or less isothernal, with minor differences in temperature not exceeding $1.0^{o}C$.

3. pH. The lowest value recorded for pool water (at 0.2 m depth), pH 6.2, is slightly above the minimum of pH 5.9 found by Trudgill (1970) for soil under *Casuarina* forest.

4. Dissolved oxygen. Among the relatively few measurements taken just before dawn, no pool became completely free of dissolved oxygen.

However it seems probable that in the deeper and more sheltered pools, the water immediately above the bottom sediments sometimes becomes anaerobic, and possibly even that occasionally a whole pool may become anaerobic. The night-time level in pool W2 fell to 0.5 mg l^{-1} at 0.2m depth (Fig. 8), while the deeper pools often showed a very marked decrease in oxygen with depth during daytime. The maximum such decrease found was a drop of 7.7 mg l^{-1} (in W9, dropping from 9.1 mg l^{-1} at the surface to 1.4 mg l^{-1} at the maximum depth of 0.73 m, at 1430 h on 19 Feb.).

5-8. Cations. As seawater has lower K/Na and higher Mg/Ca ratios than found in any of these freshwater pools, it would be expected that the more a terrestrial pools is subject to the influence of added seawater, then the nearer its ratios for these ions would approach those in seawater. The pools deviating most markedly from lines of best fit drawn for K *v.* Na and Mg *v.* Ca (Fig. 7) are:

high K/Na T1>W4>CC10>CC11 ... W6<W9<W7<CC9 high Na/K
high Mg/Ca CC9>W1>CC10>CC12>CC11 ... W2<W7<T2<W3 high Ca/Mg

Only CC9 (Bassin Flamant) combines both low K/Na with high Mg/Ca. This suggests the possibility either that this large pool is influenced by seawater more directly than any other pool, or that complicating factors are less important here than elsewhere McKenzie (1971) has suggested that freshwater in this area forms a lens floating on top of seawater. However other factors might also be important in determining cation ratios in this pool. CC9 already has a much higher cation level than many of the other pools studied, so any addition, as from animal excreta, will have less effect on the overall ratios than it would in pools with lower cation levels. Further, in spite of the considerable animal activity associated with CC9, it seems probable that visiting animals are of much less quantitative importance in relation to the volume of the pool than they are for smaller pools such as T2.

Apart from CC9, there was no obvious relationship between K/Na and Mg/Ca, suggesting that other factors such as local rock or animal behaviour probably play an important role in controlling K levels. Of the four pools with the highest K/Na ratios, T1, CC10 and CC11 are in fact subject to very high tortoise activity, and W4 to frequent visits by crabs (Table 1). If excreta from these animals is adding relatively more K than Na, this is presumably a reflection of high K/Na levels in the vegetation on which the animals feed, since selection excretion of K in preference to Na is most unlikely.

Where pools were sampled on several different occasions, Na and K levels increased through the season, roughly parallel to increases in Cl. This was probably due largely to evaporation, but as suggested above animal excreta may also sometimes make a significant contribution to the increasing levels. Data for three occasions in W2 when the depth of water was almost the same are summarized in Table 6. The

increase in K, as a fraction of seawater, was four times as great as that for Na and Cl, suggesting that bird excreta in this pool (Table 1) may be an important source of K.

If there were no factor ever leading to a loss of Na, K and Cl from pools, they would become ever more saline. However probably all pools are capable of filling up their whole catchment area and overflowing to other small catchment areas after long periods of rain. However, during the period summarized in Table 6, W2 was never diluted by rainwater sufficiently for such overflow to occur. In shallow pools lacking any well defined rim there is probably also some loss of bottom detritus due to wind erosion in the dry season. However the sides of W2 are sufficiently steep to make this explanation unlikely here.

Among the four pools whose Mg and Ca levels were followed in detail over a day's cycle (Table 5, Fig. 8) one (W7) showed a clear diurnal cycle for Ca and a possible one for Mg, two, W1 (Fig. 8) and W5, showed an erratic distribution of values suggesting that diurnal cycles might be being masked by some other effect, while one (W2) showed no indication of cyclical change. This last had the least diurnal range in pH.

Pools (W1 and W7) both had massive growths of *Oedogonium* filaments and *Plectonema gloeophilum* flocs at the time of survey, whereas these were sparse or absent in W2 and W5. Both these algae in W1 and W7 had a heavy calcareous encrustation, so presumably were important agents helping to remove Ca from solution. A diurnal cycle such as found in W7 might result from a combination of day-time removal of Ca by deposition around the surface of the algae, and a night-time release of Ca resulting from the higher levels of CO_2 present due to respiration in the pools.

9. Chloride. The increasing Cl levels found through the season suggest that data on Cl levels in pools immediately prior to drying out would be of great interest, since any organism present will presumably suffer extremely high osmotic levels, and this might well prove one of the most critical factors in their survival at a particular pool.

10-12. Phosphate. Fractions attributed to orthophosphate, polyphosphate and organic phosphate by the HACH kit methods were all well represented in the pools, and usually all three were present at levels likely to be of significance to organisms able to use these particular forms of phosphate. Examples occurred of each of the three fractions being the most abundant, but in general orthophosphate and organic phosphate were more abundant than polyphosphate.

Although levels showed considerable variation, W4 and W7 were clearly characterized as low (ortho-) phosphate pools, while W2 showed very high levels. In contrast to the four cations measured, there

was no obvious tendency for concentrations of any of the phosphate fractions to increase through the season.

13-15. Inorganic combined nitrogen. The Aldabra pools always carried moderate to very high levels of ammonia (Table 4). It seems likely that nitrite and nitrate levels were low in comparison, but due to the problem of interference by reducing substances, this is still uncertain. For instance, 10 mg urea l^{-1} causes an apparent reduction of 50% in a solution of 0.5 mg KNO_3-N l^{-1}. The results obtained for nitrite and nitrate have therefore been omitted from Tables 3, 4 and 5, but are summarized here as they do provide some clues to the situation in the pools. Only 5 out of 54 analyses in programme A gave detectable values for these ions. The values recorded were, for NO_2-N: minimum, < 0.003; maximum, 0.52, mean including W2, 0.008, mean excluding W2, < 0.003; for NO_3-N: minimum, < 0.01, maximum, 0.56, mean including W2, 0.12, mean excluding W2, < 0.01 mg l^{-1}. In one case (W2, Fig. 8), however, there was an apparent diurnal cycle of these ions, with the oxidized forms reaching a peak in the afternoon. Even then, the indicated nitrogen present in these oxidized forms represented only 3.5% total inorganic combined nitrogen.

As with orthophosphate, there was no tendency for ammonia levels in particular pools to increase through the season.

Rock analyses

Data for these are summarized in Table 7. As only 28 analyses were carried out, and little attempt made to separate recent sedimentary material from older rock, it is not possible to make any detailed comparison between chemistries and rock analyses. A few preliminary observations do however suggest that such a survey might prove of considerable interest. Two rock samples from W1 showed by far the highest Mg/Ca ratio. Similarly the highest percentage PO_4-P was recorded from rock below W2, the pool with the highest P levels in the water.

GENERAL DISCUSSION

Dynamics of soluble phosphate and nitrogenous compounds

The most striking features of the freshwater pools on Aldabra are the high levels of both dissolved phosphate and inorganic combined nitrogen often present, and the fact that the latter is apparently represented largely by ammonia-N. The main source of both phosphate and ammonia is presumably from the excreta of animals such as crabs, birds and tortoises. The high levels of organic phosphate indicate the importance of such excreta. As many of these animals carry out the bulk of their feeding away from the pools, addition of their excreta to the pools will bring about, during the wet season, a net transfer of nutrients from surrounding ecosystems to the water.

Some 60-87% of the total nitrogenous waste material in marine and freshwater crustacea is in the form of ammonia (Lockwood, 1968). In bird faeces most nitrogen occurs as excreted uric acid and amino compounds contained in the undigested food residues (Ganning and Wulff, 1969). Copeman and Dillman (1937) found that 85% of a guano sample in contact with water was converted to ammonia in 4 days. The large quantities of ammonia usually present in the pools are therefore probably in part due to direct excretion of ammonia, and part to microbial breakdown of uric acid and other organic nitrogen compounds.

It is widely assumed in the literature that in an aerobic environment ammonia will become oxidized quite rapidly as a result of microbial activity, first to nitrite and then to nitrate. It seems unlikely that the apparent near absence of such a process in pools on Aldabra can be explained entirely by the interference in analytical techniques discussed above. Ganning and Wulff (1969) reported a similar strange lack of nitrification in brackish water rockpools receiving much bird excreta by the Baltic Sea, and these authors suggested that some inhibitory substances might be present in the pools hindering oxidation of the ammonia. Although they apparently made no allowance for chemical interference in their analyses of nitrite and nitrate, they did find these ions to be relatively abundant at some seasons of the year, the overwhelming predominance of ammonia occurring only during late summer.

Neither phosphate nor ammonia showed any obvious tendency to increase in a particular pool during the season. As the algal standing crops also did not show any marked increase during the season (see next paper), accumulation by these organisms is unlikely to be a major cause of net removal of these nutrients. The very high pH values occurring during the afternoon in some pools are probably a significant cause of the loss of NH_4-N, as a result of the ammonia - water equilibrium, $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$, being displaced towards the right-hand side. An odour of ammonia was sometimes detectable in the vicinity of several pools on Aldabra. Removal of soluble phosphate is less easily explained, though probably precipitation of calcium phosphate is one significant cause.

Comparisons with waters in other regions

Several examples exist in the literature of waters with levels of phosphate and inorganic combined nitrogen rather similar to those of the pools on Aldabra, excluding pool W2. Howmiller (1969) suggested that the hypersaline Arcturus Lake on Genovesa Island, Galapagos, is an outstanding example of guanotrophy. The nutrient levels reported for this lake were 0.46 mg l^{-1} PO_4 and 0.45 mg l^{-1} NO_3-N; ammonia was at a low level in comparison with nitrate. The rockpools described from the Baltic by Ganning and Wulff (1969) showed variation from one to another and also throughout the year; the maximum levels reported were 0.731 mg l^{-1} PO_4-P and 0.325 mg l^{-1} NH_4-N.

It is difficult to find any reports of waters carrying the levels of phosphate and inorganic combined nitrogen found in pool W2, and which

are not polluted by sewage or some other human activity. A pond in Hyderabad studied by Seenayya (1971) provides a fairly close parallel, but this pond (Golkonda Pond) is heavily polluted by sewage.

ACKNOWLEDGEMENTS

We are most grateful to the Royal Society and the Natural Environment Research Council for financial support and encouragement in our research on Aldabra, and for the help in collecting data provided by, among others, L.U. Mole, F.W. Topliffe, J.R. Wilson and H. Charles, for helpful discussion with Dr. S. Trudgill, for analyses by W. Simon, T. Brett, P.J. Say and Mrs. G.A. Walker, and for typing by Mrs. V. Evans.

REFERENCES

Baker, B.H. 1963. Geology and mineral resources of the Seychelles Archipelago. *Mem. geol. Surv. Kenya* 3: 1-140.

Braithwaite, C.J.R., Taylor, J.D. and Kennedy, W.J. 1973. The evolution of an atoll: the depositional and erosional history of Aldabra. *Phil. Trans. R. Soc.* B 266: 307-340.

Copeman, P.R. v.d. R. and Dillman, F.J. 1937. Changes in the composition of guano during storage. *J. agric. Sci.* 27: 178-187.

Fosberg, F.R. 1971. Preliminary survey of Aldabra vegetation. *Phil. Trans. R. Soc.* B 260: 215-225.

Ganning, B. and Wulff, F. 1969. The effects of bird droppings on chemical and biological dynamics in brackish water rockpools. *Oikos* 20: 274-286.

Howmiller, R.P. 1969. Studies on some inland waters of the Galapagos. *Ecology* 50: 73-80.

Lockwood, A.P.M. 1968. *Aspects of the Physiology of Crustacea.* 328 pp. Oliver & Boyd, London & Edinburgh.

McKenzie, K.G. 1971. Entomostraca of Aldabra, with special reference to the genus *Heterocypris* (Crustacea, Ostracoda). *Phil. Trans. R. Soc.* B 260: 257-298.

Seenayya, G. 1971. Ecological studies on the plankton of certain freshwater ponds of Hyderabad - India. I. Physico-chemical complexes. *Hydrobiologia* 37: 7-31.

Stoddart, D.R. 1971a. Scientific studies at Aldabra and neighbouring islands. *Phil. Trans. R. Soc.* B 260: 5-30.

Stoddart, D.R. 1971b. Place names of Aldabra. *Phil. Trans. R. Soc.* B 260: 631-632.

Stoddart, D.R. and Mole, L.U. (in press) Climate of Aldabra Atoll.

Sverdrup, H.U., Johnson, M.W. and Fleming, R.H. 1946. *The Oceans, their physics, chemistry and general biology.* 1087 pp. Prentice-Hall, N.Y.

Trudgill, S.T. 1972. *Process Studies of limestone erosion in littoral and terrestrial environments, with special reference to Aldabra Atoll, Indian Ocean.* Ph.D. Thesis, University of Bristol, England.

Westoll, T.S. and Stoddart, D.R. (eds) 1971. A Discussion of the results of the Royal Society Expedition to Aldabra 1967-68. *Phil. Trans. R. Soc.* B 260: 654 pp.

Table 1 Geographical and other background data on pools studied. A, Aldabra Limestone; PC, Picard Calcarenites; T, Takamaka Limestone.

no.	Fig., if illus.	grid. ref.	geology	local name of pools or area	surrounding vegetation	shading
West Island						
W1	2, 3	0677,+1197	A	near Anse Var	mixed scrub, *Plumbago aphylla* dwarf scrub	+
W2	4	0630,+0997	PC	near Bassin Cabri	sparse	none
W3		0620,+0990	PC	near Bassin Cabri	sedge meadow	none
W4	5	0593,+0961	T	track to Bassin Cabri	mixed scrub, scrub forest	+
W5		0565,+1015	A	near Settlement	*Casuarina* forest	+++
W6		0565,+1016	A	near Settlement	*Casuarina* forest	+++
W7	6	0580,+0957	A	near Settlement	mixed scrub, scrub forest	++
W9		0579,+0956	A	near Settlement	mixed scrub, scrub forest	++
W10		0590,+0917	A or T?	near Settlement	mixed scrub, scrub forest	++
W102		0574,+1022	A	near Settlement	mixed scrub, scrub forest	++
W103		0576,+1032	T or A?	near Settlement	mixed scrub, scrub forest	+++
South Island, Takamaka						
T1		3342,+0590	T	Bassin Ibis	sedge meadow, mixed scrub	none
T2		3345,+0550	T	Bassin Takamaka	*Calophyllum, Ficus, Maillardia* scrub forest	++
South Island, Cinq Cases						
CC2		3800,+0625	T or A?	near Cinq Cases lagoonal camp	*Thespesia populnea* thicket	+
CC5		3850,+0612	A	Cinq Cases	*Pandanus* Grove	none
CC8		3960,+0595	A	Cinq Cases, near Coast	sparse	+
CC9		3902,+0792	A	Bassin Flamant	mixed scrub, scrub forest	none
CC10		3965,+0620	A	near Cinq Cases camp	mixed scrub, scrub forest	none
CC11		3930,+0787	A	track to Bassin Flamant	mixed orthophyll tortoise pasture	none
CC12		3912,+0601	A	near well, Cinq Cases	*Cyperus ligularis* meadow	+

Table 1. Geographical and other background data on pools studied. A, Aldabra Limestone; PC, Picard Calcarenites; T, Takamaka Limestone.

no.	bottom of pool	approx. max. surface (m^2)	max. depth of water recorded (m)	degree of permanence 72/73 wet season	crab	tortoise	bird	no. of times water sampled
West Island								
W1	detrital mud	3.5 x 1.5	0.72	permanent	++		+	7
W2	detrital mud	2.0 x 0.5	0.31	permanent	++		+++	6
W3	calcareous mud	2.0 x 2.0	0.075	very transient	+	+	+	3
W4	calcareous mud	2.9 x 1.2	0.76	permanent	+++			6
W5	*Casuarina* needles	2.4 x 1.3	0.91	permanent	+			6
W6	*Casuarina* needles	1.5 x 1.0	0.19	permanent	+			4
W7	*Casuarina* needles	6.0 x 4.3	0.51	permanent	++	+		6
W9	*Casuarina* needles	1.7 x 1.4	0.73	permanent	++			3
W10	calcareous mud	3.0 x 1.5	0.10	transient	+			1
W102	detrital mud	1.0 x 0.5	0.07	permanent	+			1
W103	detrital mud	0.75x 0.5	0.05	permanent	+			1
South Island, Takamaka								
T1	detrital mud	60 x 35	0.75	permanent	+	+++	++	1
T2	fine sediment	20 x 15	0.80	permanent, (? all year)	+	+++	+	2
South Island, Cinq Cases								
CC2	detrital mud	5 x 2	0.15	permanent	++			1
CC5	detrital mud	6 x 5	0.15	permanent	+	++		2
CC8	calcareous mud	1 x 1	0.4	permanent	+	+		1
CC9	fine sediment	c. 100 x 100	1.5 - ?2.0	permanent	+	+	+	1
CC10	fine sediment	20 x 10	0.3	permanent	+	+++		1
CC11	fine sediment	10 x 10	0.1	transient	+	++		1
CC12	detrital mud	5 x 4	0.1	permanent	+	+		1

Table 2. Sampling programme for water chemistry.

A samples, excluding repeats for 24 h surveys (see text) = 54
B total samples = 136

Analyses for individual parameters

	no. of pools sampled	no. analyses in programme A	no. analyses in programme B
maximum possible	20	55	137
OD_{420nm}	16	24	92
temperature	17	52	134
O_2	17	50	130
pH	20	54	135
Na	16	27	92
K	16	27	92
Mg	16	27	92
Ca	16	27	92
Cl	19	27	92
ortho PO_4-P	20	55	94
"poly" PO_4-P	11	25	25
organic PO_4-P	11	24	24
ammonia-N	20	55	100
NO_2-N	20	55	100
NO_3-N	20	55	100

Table 3. Summary of data on physical and chemical parameters for water in pools. Mean values are based on programme A, minimum and maximum ones on programme B. Values added in brackets are extremes found during spot readings taken anywhere in freshwaters on Aldabra. Concentrations are in mg l^{-1}. (In calculation of means, non-detectable values are treated as zero).

	minimum	maximum	mean (including W2)	mean (excluding W2)
$O.D._{420}$	0.021	0.273	0.084	0.088
temperature	24.9^{o} (23.0^{o})	37.2^{o} (41.2^{o})		
pH	6.6 (6.2)	10.8 (11.8)		
O_2 (%)	6 (5)	255		
O_2 (conc.)	0.5 (0.4)	18.2		
Na	7.2	696	186	128
K	0.82	59.0	16.6	12.0
Mg	2.6	86.6	22.5	19.7
Ca	26.4	156	59.7	55.8
Cl	20	1590	286	255
orthophosphate-P	0.01	12.3	1.13	0.53
"polyphosphate"-P	<0.01	3.8	0.58	0.40
organic phosphate-P	0.06	10.3	1.34	1.05
ammonia-N	0.2	45	3.46	1.47

Table 4. Summary of some of chemical data for individual pools. Mean values are based on programme A, minimum and maximum ones on programme B. Numbers of samples for each programme in each pool are indicated. (The total for all pools is sometimes one more than that in Table 2, because pools W5 and W6 were joined together on one date, and the single results are used twice in Table 4). Concentrations are in mg l^{-1}.

		W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12
Na	no.B	17	19	1	3	10	2	10	1												
	min.	34.1	104		7.2	37.5	109	66													
	max.	98.5	414		22	102	222	118													
	no.A	3	3	1	3	3	2	3	1		1	1	1	1		1		1	1	1	1
	mean	73.9	277	196	15.2	80.0	166	92.5	49.7		121	103	99.5	685		176		637	244	38.4	386
K	no.B	17	19	1	3	10	2	10	1												
	min.	2.4	18.1		0.82	3.2	7.0	2.7													
	max.	11.9	64.0		3.9	8.0	13.3	21.5													
	no.A	3	3			3	2	3	1		1	1	1	1		1		1	1	1	1
	mean	5.1	44.5	11.7	2.7	7.5	10.2	11.3	2.6		7.7	9.3	24.0	59.5		17.8		34.0	49.0	7.0	24.0
Mg	no.B	17	19	1	3	10	2	10	1												
	min.	6.7	24.0		2.6	10.2	20.4	10.2													
	max.	23.9	62.8		4.7	18.7	28.0	24.3													
	no.A	3	3	1	3	3	2	3	1		1	1	1	1		1		1	1	1	1
	mean	16.3	44.9	14.8	3.3	15.3	24.2	18.8	10.1		18.7	21.0	23.5	85.1		23.3		67.5	32.5	9.5	41.2
Ca	no.B	17	19	1	3	10	2	10	1												
	min.	26.3	65.3		26.4	50.2	59.5	43.0													
	max.	59.2	112		32.9	55.6	79.0	83.2													
	no.A	3	3	1	3	3	2	3	1		1	1	1	1		1		1	1	1	1
	mean	43.6	90.3	99.0	29.8	57.0	69.8	72.1	55.0		59.6	62.7	74.8	146		48.1		49.4	45.5	41.4	62.2
Cl	no.B	17	19	1	3	10	2	10	1												
	min.	62	182		20	58	176	82													
	max.	201	880		70	225	461	266													
	no.A	3	3	1	3	3	2	3	1		1	1	1	1		1		1	1	1	1
	mean	136	556	490	43	158	319	174	78		49	144	182	1250		334		1260	454	80	766
ortho PO_4-P	no.B	11	11	3	3	11	5	10	3	6			4	5		2					
	min.	0.17	3.3	0.13	0.05	0.23	0.07	0.03	0.10	0.05			0.17	0.9		0.30					
	max.	0.40	10.0	0.6	0.30	1.0	0.70	0.23	0.50	0.20			0.23	12.3		1.90					
	no.A	7	6		6	5	5	6	3	1	1	1	1	2	1	2	1	1	1	1	1
	mean	0.38	6.1	0.40	0.11	0.74	0.47	0.14	0.32	0.20	0.43	0.30	0.17	3.5	0.20	1.1	0.97	0.10	0.33	0.27	0.43
"poly"PO_4-P	no.B	4	3	3	2	3	3	3	2												
	min.	<0.01	1.3	<0.01	0.17	0.18	0.10	0.07	0.30												
	max.	0.50	2.3	0.17	0.33	3.80	0.23	0.20	0.33												
	no.A	4	3	3	2	3	3	3	2						1	1	1				
	mean	0.19	1.79	0.11	0.25	1.40	0.17	0.14	0.32						0.13	0.34	0.40				

Table 4 (continued)

		W1	W2	W3	W4	W5	W6	W7	W9	W10	W102
organic PO_4-P	no.B	3	3	3	2	3	3	3	2		
	min.	0.10	2.3	0.06	0.23	0.17	0.17	0.17	0.20		
	max.	0.23	2.7	0.3	0.30	0.30	1.07	0.33	0.23		
	no.A	3	3	3	2	3	3	3	2		
	mean	0.17	2.34	0.22	0.26	1.20	0.46	0.23	0.22	6	
ammonia-N	no.B	17	17	3	6	11	5	10	3	0.45	
	min.	0.2	0.6	0.6	0.4	0.7	0.8	0.07	0.50	0.65	
	max.	1.2	45.0	1.3	0.6	1.5	1.5	2.0	2.0		
	no.A	7	6	3	6	5	5	6	3	1	1
	mean	0.52	19.2	1.1	0.50	1.1	1.1	1.9	2.9	0.5	0.90

		W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12
organic PO_4-P	no.B										
	min.										
	max.										
	no.A				1	1	1				
	mean				0.3	10.0	10.3				
ammonia-N	no.B		4	5		2					
	min.		6.0	0.7		0.60					
	max.		10.5	15.0		0.80					
	no.A	1	1	2	1	2		1	1	1	1
	mean	0.90	10.5	7.8	0.40	0.70	0.80	0.50	1.4	2.3	1.2

Table 5. Lower and upper limits for parameters found during 24 h surveys of pools; only those parameters showing an obvious diurnal cycle are included. All concentrations are in mg l^{-1}.

	W1 5/6 June		W2 5/6 June		W5 2/3 May		W7 2/3 May		W10 29/30 March	
	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
temp.	23.8	27.6	24.9	32.0	27.0	31.7	28.1	36.7	26.5	40.2
pH	7.1	8.7	7.5	8.0	7.4	9.7	7.4	8.6	7.7	10.1
O_2	2.8	11.4	0.4	10.6	0.9	15.4	0.8	9.8	5.1	>14.0
Mg	20.9	23.9	c. 60, no cycle		c. 15, no cycle		18.9	22.5	no data	
Ca	50.0	58.0	c. 108, no cycle		c. 55, no cycle		73.4	90.1	no data	
ortho P	0.17	0.43	6.3	7.0	0.43	1.0	c. 0.03, no cycle		0.05	0.19
NH_4-N	0.6	1.2	25	30	0.8	1.5	1.1	2.0	0.5	0.65

Table 6. Changes in pool W2 of various parameters over a 3-month period. Concentrations are in mg l^{-1}

	max. depth	Na	K	Mg	Ca	Cl	ortho-P	NH_4-N
on 6.3.73	0.22 m	104	18.1	24.0	65.3	182	5.3	24
on 20.5.73	0.23	332	55.0	51.0	98.0	700	5.8	45
on 5.6.73	0.24	385	60.5	59.7	108	785	7.7	31
change between first and last	+0.02	+281	+42.4	+35.7	+33	+503	+2.4	+7
ratio of increase to conc. in seawater		.026	.11	.025	.09	.026		

231-339 O - '77 - 10

Table 7. Analyses of rock samples taken from sides of pools. Values given are for material soluble in 25% HCl as a percentage of the total rock, including soluble component.

	min.	max.	mean
Mg	0.22	1.92	0.54%
Ca	27.6	33.1	29.7%
P	0.01	0.17	0.05%

Fig. 2. Pool W1 at beginning of wet season. Note massive flocs of floating *Oedogonium*.

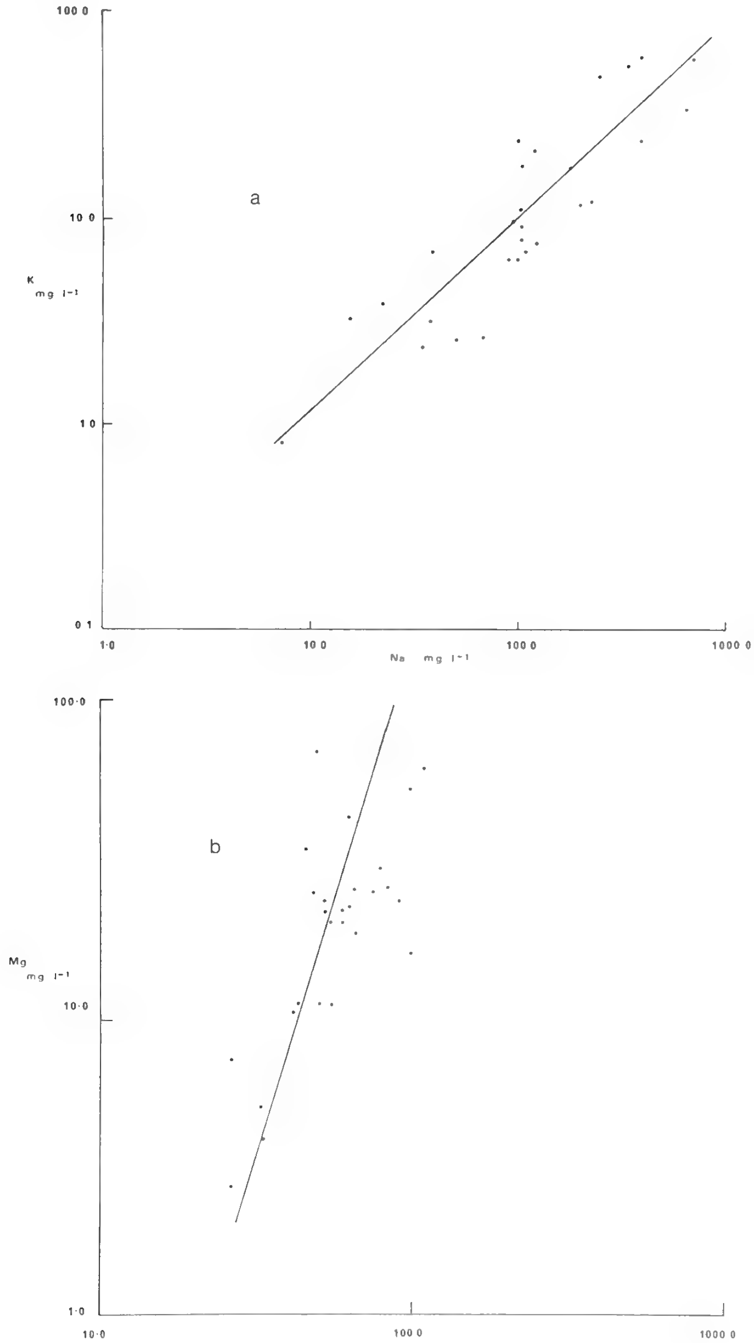
Fig. 3. Pool W1 near end of wet season, showing its steep sides exposed as pool dried out. Marker in this (and subsequent figures) is 1m long.

Fig. 4. Pool W2, when almost full. The surrounding white, terrestrial areas are ones which lack the normal *Tolypothrix byssoidea* algal cover.

Fig. 5. Pool W4. Note sharp boundary between the terrestrial rock which is never submerged, and which appears dark due to growths of *Tolypothrix byssoidea*, and the now exposed upper part of the pool which has a cover of *Calothrix parietina*.

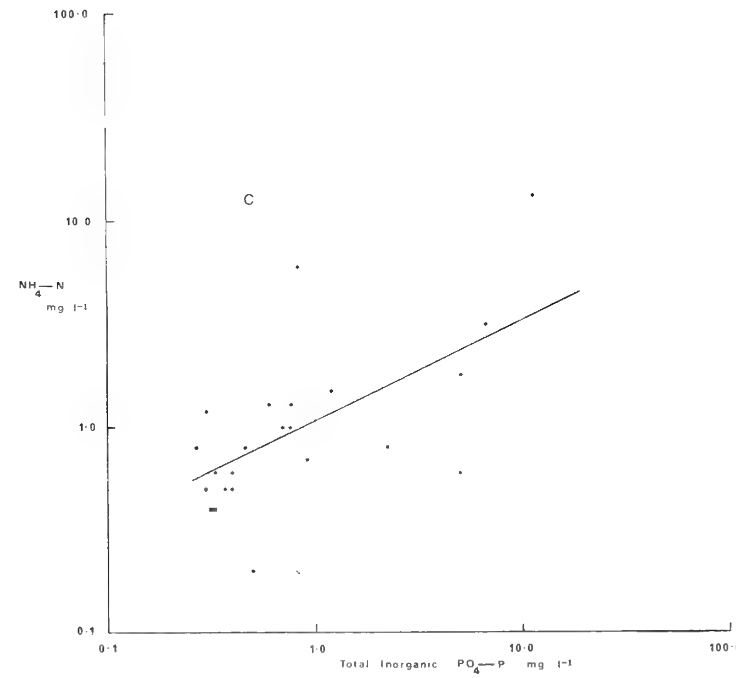
Fig. 6. Pool W7, when relatively low. Note flocs of *Closterium* floating on the surface, and the black mud already deposited as the pool dries out.

Fig. 7. Relationship between various pairs of ions studied in programme A:



a) log K v log Na, regression coefficient = 0.9, correlation coefficient = 0.9

b) log CA v log Mg, regression coefficient = 3.4, correlation coefficient = 0.5



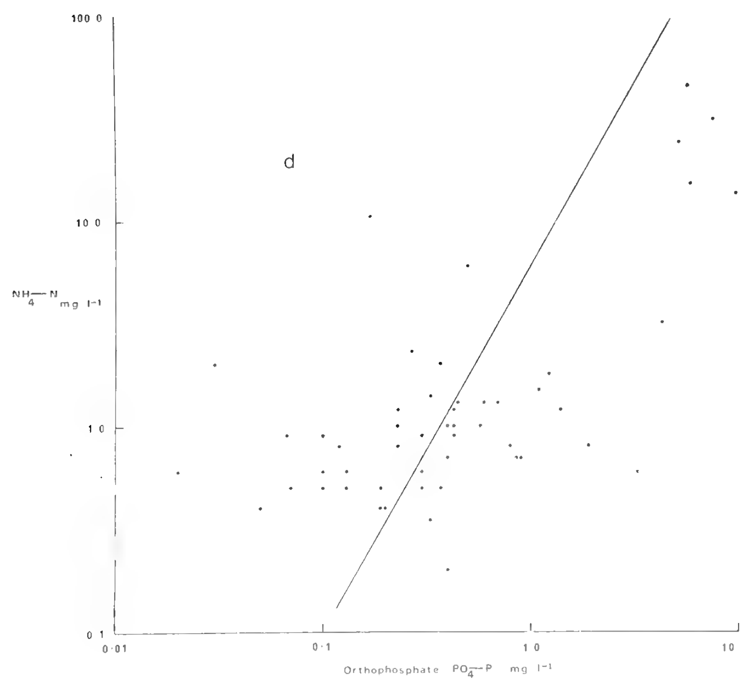


Fig. 7 (con.)

c) log NH_4-N v log total inorganic PO_4-P regression coefficient = 0.5 correlation coefficient = 0.7

d) log N v log ortho PO_4-P, regression coefficient = 1.8, correlation coefficient = 0.8

Fig. 8. Diurnal cycles of various parameters in pools W1 and W2 (on 5/6 June 1973)

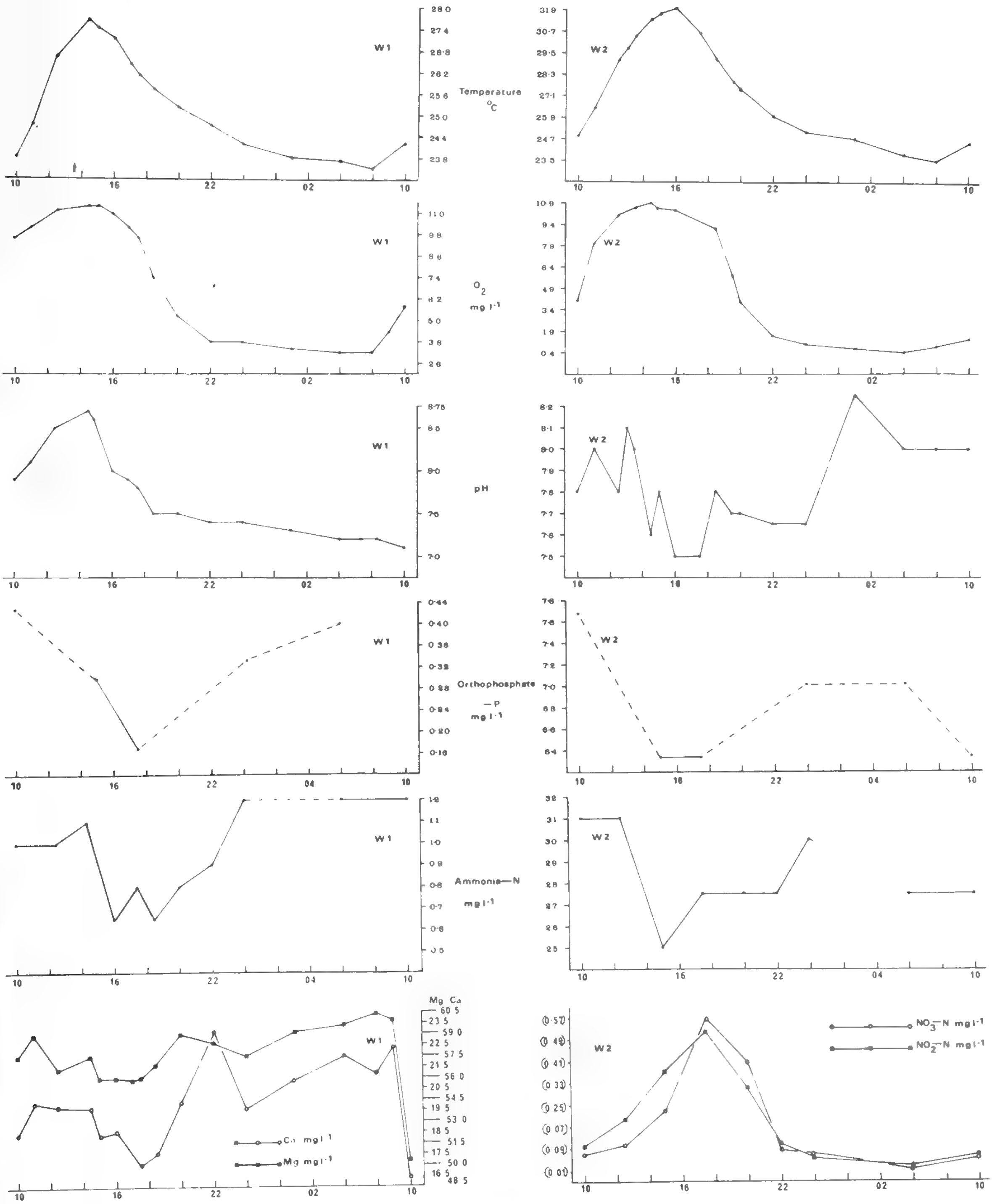
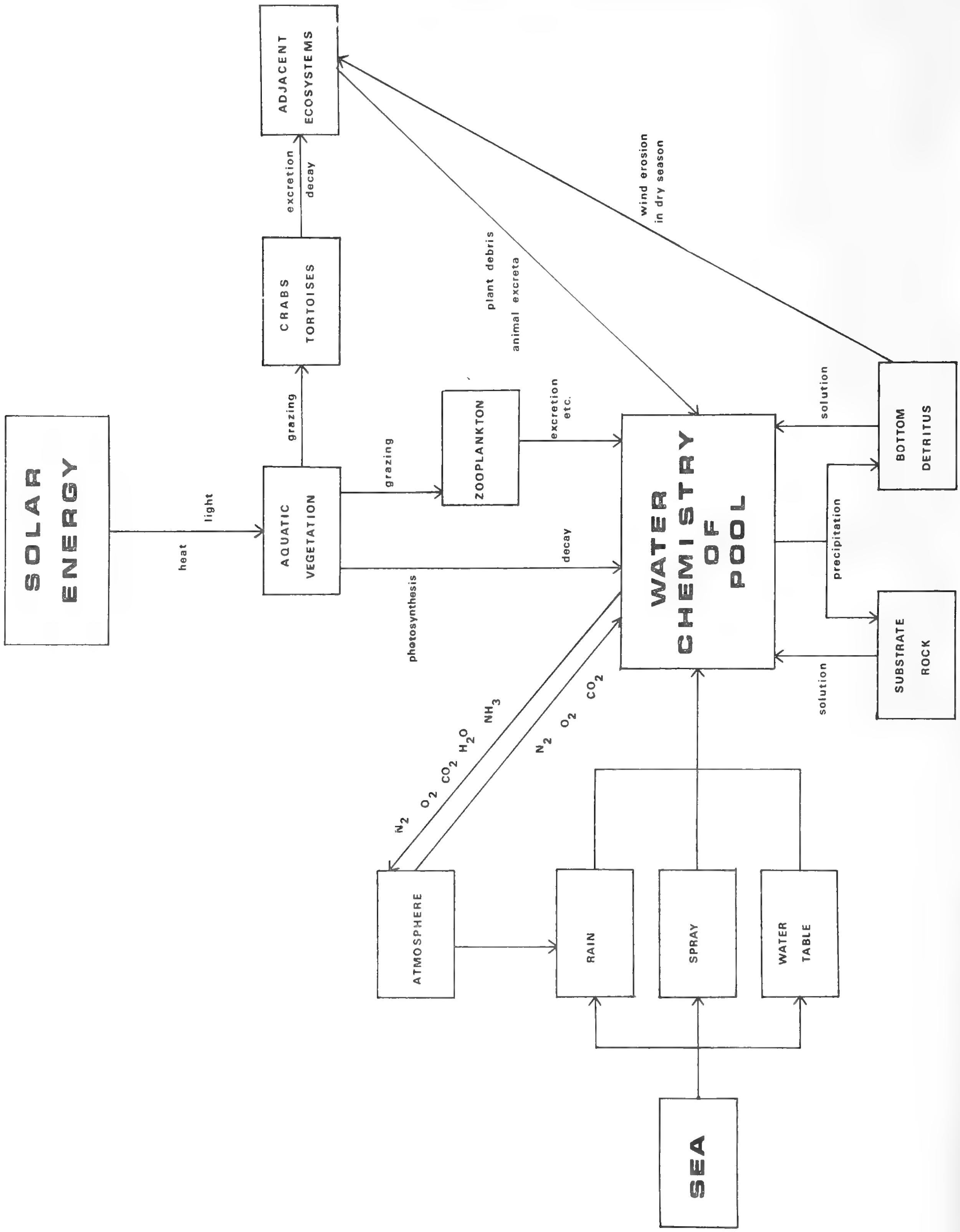


Fig. 9. Diagrammatic illustration of some important factors likely to influence pool chemistry.



ATOLL RESEARCH BULLETIN
NO. 214

OBSERVATION ON REDOX POTENTIAL IN FRESHWATER POOLS ON ALDABRA

by B. A. Whitton and M. Potts

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

OBSERVATION ON REDOX POTENTIAL IN FRESHWATER POOLS ON ALDABRA

by B. A. Whitton and M. Potts [1]

ABSTRACT

In comparison with most values reported in the literature for freshwaters, small freshwater pools on Aldabra were found always to have values for redox potential which were low, the great majority lying below + 200 mV at a standard pH of 7.0, using a correction of 58 mV per unit pH difference from the standard pH. Values were especially low in pools in *Casuarina* forest, where readings below + 50 mV were recorded frequently. Typical freshwater pools on Aldabra combine a well oxygenated environment with low redox potential, an environmental combination which has received little investigation in the literature.

INTRODUCTION

In a previous study of the chemistry of freshwater pools on Aldabra (Donaldson and Whitton, 1976), it was found that most of the inorganic nitrogen present was apparently in the form of ammonia rather than nitrite or nitrate. This occurred in spite of the fact that the pools were often highly super-saturated with oxygen by daytime. The only other observations in the literature reported a similar (apparent) loack of nitrification are those made by Ganning and Wulff (1969) in brackish rockpools by the Baltic Sea. These latter authors suggested that some inhibitory substances might be present in the pools which hindered oxidation of ammonia.

Since the previous account of the pools on Aldabra, the present authors have had the opportunity to collect further data from the atoll which would help account for any lack of nitrification. A full report of these will be published elsewhere, but a summary of observations on redox potential in the pools is given here in order that it may be read together with the previous account. These observations were all made during the period December 1974 - January 1975.

---

[1]Department of Botany, University of Durham, Durham, England.
(Manuscript received 8 July 1975 --Eds.)

METHODS

The system used for naming the pools has been described in the previous account (Donaldson and Whitton, 1976).

Measurements of redox potential were made using a PYE UNICAM portable meter model 293 with PYE UNICAM combined redox electrodes, these consisting of a platinum indicator electrode and a silver / silver chloride reference system. Cleaning and buffering of the electrode was made at frequent intervals during sampling. The Pt indicator electrode was first cleaned by rubbing gently with emery paper and then immersing in concentrated, chlorine-free HNO_3. It was then rinsed and calibrated against a redox buffer. Measurements of pH were taken at the same time as redox potential, using a similar meter, but with a pH electrode. Data on redox potential is reported here both as a direct reading (Eh) and one "corrected" to pH 7.0 (Eh_7). Due to wide diurnal fluctuations in pH, it is essential to make some initial comparison of results with redox potential values corrected to a standard pH value. The correction value of 58 mV per unit pH used in the earlier literature was used here. Where simple tests of adding acid or alkali to samples of pool water were carried out, these did in fact indicate that this was a reasonable choice of correction value.

It was unfortunately not possible to take measurements of dissolved oxygen simultaneously with those of redox potential due to loss of equipment on route to the atoll. However observations on ammonia, nitrite, nitrate, phosphate and algal vegetation indicated that the behaviour of the pools was in general very similar during the present period of study to that during the previous period.

RESULTS

Of the 20 pools whose chemistry was described by Donaldson and Whitton (1976), six were chosen for detailed study of redox potential changes with depth and time on 17 January 1975. Part of the data obtained is summarized in Table 1. As the sediment surface tends to be both ill-defined and a region of rapid change, not too much attention should be paid to small differences between readings taken immediately above the sediment surface.

In addition to these readings, measurements were taken in other small pools on 17 January, and also in a range of pools on other dates. These somewhat extended the upper range of redox potential values, the highest being a small pool filled with *Oedogonium:*

	t	pH	Eh	Eh_7
0950 h	28.9	7.50	+ 245 mV	+ 274 mV

All freshwater pools found with an Eh_7 value in the water near the surface of the pool lower than + 50 mV (including W7, W8, W9) were associated with the *Casuarina* Forest, and had waters coloured a pale

brown.

DISCUSSION

These data are obviously fragmentary, and any conclusions should be treated with caution until a more intensive study has been carried out on them. Nevertheless they do indicate the probability of several features of interest.

1. All the pools showed marked variations in redox potential during the day. As repeated readings at any one time were consistent, and as the pattern of changes was quite different in different pools, it seems unlikely that these variations were associated with any sort of instrument error. It may be pointed out that the pool which showed an increase between successive readings during the day, W2, is also the pool for which Donaldson and Whitton (1976) reported a late afternoon peak in nitrite and nitrate values.

2. In comparison with data for soils and lake sediments, the literature on values for redox potential in freshwaters is rather sparse. It would however seem clear from the literature available (Baas-Becking *et al.*, 1955; Hutchinson, 1957) that in comparison with most oxygenated waters, the values for pools on Aldabra are low, and those for the pools in the *Casuarina* Forest remarkably low.

3. If freshwaters behave in a manner similar to soils (Pearsall, 1938; Reddy and Patrick 1975), then the redox potential measurements recorded for the majority of Aldabra pools correspond with environments which do not favour nitrification. If the values quoted by Pearsall (1938) are corrected to Eh_7 values, then he found that with only three exceptions, all soils studied where nitrate predominated over ammonia had an Eh_7 greater than + 234 mV, and soils lacking nitrates had an Eh_7 less than 204 mV. The three exceptions found by Pearsall were all soils receiving drainage from stream waters containing nitrate.

These observations would provide an explanation for the rarity of detectable nitrate in Aldabra pools. In most instances the redox potential values correspond to an environment which is sufficiently reducing that nitrification would not be expected to occur. Further, pool sediments were always found to be markedly reducing, and as the sediments are in many cases disturbed frequently by the activity of crabs, any chemical changes taking place in the sediments may be expected to have a marked effect on the chemistry of the water above the sediment.

It is less clear what are the probable agents responsible for bringing about these low redox potential measurements. The fact that all the pools in the *Casuarina* Forest had low values suggests that the brown materials leaching from the debris of "needle" and other fallen parts of the tree may here be partly responsible. However the variations taking place during a single day within one pool suggest that some other quite different factors must play a role. Disturbance

of the sediments and release of excreta by crabs would seem likely such factors.

ACKNOWLEDGEMENTS

We are most grateful to the Royal Society and the Natural Environment Research Council for financial support.

REFERENCES

Baas Becking, L. G. M., Kaplan, I. R. and Moore, D. 1960. Limits of the natural environment in terms of pH and oxidation-reduction potential. *J. Geol.* 68: 243-284.

Donaldson, A. and Whitton, B. A. 1976. Chemistry of freshwater pools in Aldabra Atoll. *Atoll Research Bulletin,* this issue.

Ganning, B. and Wulff, F. 1969. The effect of bird droppings on chemical and biological dynamics in brackish water rockpools. *Oikos* 20: 274-286.

Hutchinson, G. E. 1957. *A Treatise on Limnology*. 1. *Geography, Physics and Chemistry*. 1015 pp. John Wiley & Sons Inc., N.Y., U.S.A.

Pearsall, W. H. 1938. The soil complex in relation to plant communities 1. Oxidation-reduction potentials in soils. *J. Ecol.* 26: 180-193.

Reddy, K. R. and Patrick, W. H., Jr 1975. Effect of alternate aerobic and anaerobic conditions on redox potential, organic matter decomposition and nitrogen loss in a flooded soil. *Soil Biol. Biochem.* 7: 87-94.

Table 1 Temperature (°C), pH and redox potential (mV) values for six pools (see text)

Position in pool and time of day	W2				W3				W4				W7				W8				W9			
20 mm below surface of pool	t	pH	Eh	Eh_7	t	pH	Eh	Eh_7	t	pH	Eh	Eh_7	t	pH	Eh	Eh_7	t	pH	Eh	Eh_7	t	pH	Eh	Eh_7
0820-1030	25.8	6.25	+100	+57	28.8	7.35	+120	+140	29.8	8.39	+172	+253	29.9	6.20	+225	+179	28.4	6.31	+78	+38	28.0	6.58	+80	+56
1425-1455	33.4	7.95	+100	+155	40.2	9.35	-85	+51	37.2	10.18	+15	+199	41.5	7.80	-60	-14	31.7	6.22	-48	-93	31.7	6.76	+58	+44
1810-1850	32.8	7.8	+180	+226	32.2	8.60	+45	+138	34.2	10.0	-10	+164	35.1	7.60	+10	+45	29.2	8.0	-130	-72	29.6	7.65	-80	-42
over surface of sediment																								
0820-1030	25.2	5.58	+45	-37	28.5	7.40	-80	-57	29.2	7.90	+165	+217	28.2	6.22	+75	+30	28.3	5.90	+25	-39	28.2	6.25	+105	+62
1425-1455	32.2	7.10	-95	-89	32.3	7.10	-95	-89	40.2	7.25	-182	-167	40.8	7.53	-58	-27	31.3	6.09	-92	-145	30.8	6.70	-15	-32
1810-1850	30.8	7.4	-140	-117	32.4	8.70	+10	+109	33.8	9.6	-40	-111	35.8	7.80	-40	+6	29.2	8.0	-180	-122	29.4	7.80	-160	-114
100 mm below surface of sediment																								
0820-1030	25.8	5.15	-395	-502	28.2	6.35	-248	-286	29.3	6.25	-15	-59	28.3	6.25	-45	-84	28.1	5.98	-120	-178	28.3	5.96	-85	-145
1425-1455	30.2	6.45	-338	-370	38.2	6.82	-208	-218	32.8	7.20	-148	-136	36.9	6.65	-192	-212	31.3	6.10	-183	-235	29.9	6.75	-182	-197
1810-1850	30.2	7.0	-260	-260	33.6	8.65	-192	-96	33.8	9.2	-180	-52	35.2	7.80	-240	-194	29.3	7.65	-240	-182	29.0	7.68	-260	-221

231-339 O - '77 - 11

ATOLL RESEARCH BULLETIN
NO. 215

ALGAL FLORA OF FRESHWATER HABITATS ON ALDABRA

by A. Donaldson and B. A. Whitton

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

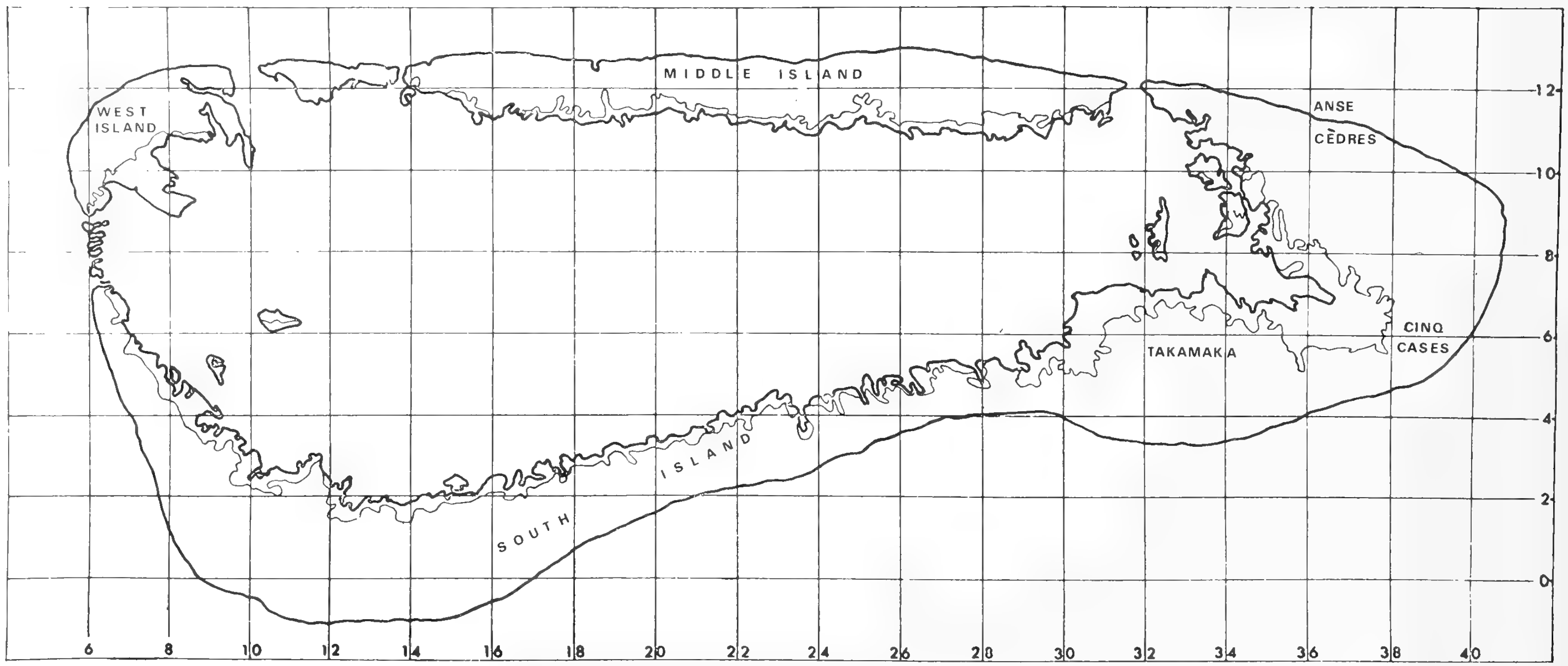


Fig. 1. Aldabra, showing location of places mentioned in text.

ALGAL FLORA OF FRESHWATER HABITATS ON ALDABRA

by A. Donaldson and B. A. Whitton [1]

ABSTRACT

An account is given of the algal flora of freshwater habitats on Aldabra, together with ecological notes for each species. The distribution of these species in 20 pools chosen for more detailed study is summarized. Based on their occurrence within these 20 pools, the most widespread species are: *Lyngbya* sp., ≤ 1 μm (20); *Calothrix parietina* (15); *Phormidium mucicola* (15); *Lyngbya nordgardhii* (14); *Oscillatoria pseudogeminata* (14); *Phacus orbicularis* (13).

INTRODUCTION

Although freshwaters cover only a small part of the surface of Aldabra, they nevertheless provide a wide variety of habitats for algae. They range, for instance, from shallow depressions holding water for only a few hours to pools permanent throughout the wet season. The physical and chemical parameters of the water may also show considerable variation, as has already been described in the previous paper (Donaldson and Whitton, 1976). Preliminary observations (Whitton, 1971) indicated that the algal flora of freshwater pools was sometimes quite rich in species, so this habitat was chosen for more detailed study in the survey carried out during the wet season. The following account summarizes the floristic observations made during this survey.

METHODS

Location of pools and sampling programme

Observations were made on pools on West Island, Middle Island and South Island. The pools chosen for especially detailed sampling

---

[1] Department of Botany, University of Durham, Durham, England
Manuscript received 8 July 1975 -- Eds.)

included the 20 whose nomenclature and chemistry were described by Donaldson and Whitton (1976), together with a further 79 mostly in the Takamaka, Cinq Cases and Anse Cèdres regions. The maximum level of Cl recorded in the chemical survey of pools was 1260 mg l^{-1} in CC9 (± = 2.3‰ salinity).

It seems probable that almost all the other pools used for observations were, at any particular stage of drying out, less saline than CC9. However it also seems probable that most pools reach high salinity values towards the end of the wet season. CC9, recorded by us as 2.3‰, was reported to have a salinity of 1.5‰ by McKenzie (1971).

Unless stated otherwise, records were made during the wet season, November 1972 - June 1973. A brief comparison is however added of observations made in December 1968 - January 1969.

The 20 pools listed in Table 1 were sampled on the following number of occasions: W1, 6; W2, 8; W3, 7; W4, 8; W5, 7; W6, 7; W7, 8; W9, 8; W10, 1; W102, 1; W103, 1; T1, 3; T2, 3; CC2, 3; CC5, 3; CC8, 2; CC9, 3; CC10, 1; CC11, 1; CC12, 1. Although only a few details are included here, quantitative plankton counts were made for pools W1, W2, W3, W4, W5, W6, W7 and W9.

Samples were taken from each obvious microhabitat within a pool. The principle microhabitats (together with abbreviations used throughout the text) were as follows:

F floating at or near the surface (including neuston)
P plankton
Ep epilithic
En endolithic
El epipelic
Et epiphytes
A aufwuchs, not including true epiphytes.

Other microhabitats occurring occasionally included dead wood, leaves and structures resulting from man's activities.

The species recorded are all based on direct microscopy observations. A much fuller list would no doubt have resulted if culture techniques had been used, since under these conditions not only might a few of the rarer plankton species have had an opportunity to develop, but probably also many of the widespread terrestrial species.

Taxonomic

The eukaryotes named have been identified using the floras standard for the respective groups. Although it has so far not proved possible to name the remaining forms, this is in most cases for lack of reproductive stage or because the groups require specialist help. The authors can supply further details of these forms to any workers dealing with algae on other atolls. The separation of the two *Closterium* forms

termed here sp. A and sp. B did however cause difficulty. Sometimes the two forms were quite distinct, whereas on other occasions material was present which appeared intermediate.

The problems involved in naming the blue-green algae (Myxophyta) were rather different. There are several quite different approaches available in the literature for treating these organisms, but none are ideal for producing a descriptive account of field populations including a wide range of forms. The method used in the preparation of this account was as follows. As far as possible, a binomial was allocated using the conventional floras, in particular those of Geitler (1932), Desikachary (1959) and Starmach (1966). For some genera where the limits between species as originally described appear to be based almost entirely on rather arbitrary size (trichome width) limits, we have divided up the overall size range in a more systematic manner, following the practice already adopted by Golubić (1967). We have then used the conventional binomial which corresponds most closely to the modified size limits. These latter are added after the binomial and the author responsible for the original description. The genera treated in this manner are: *Aphanocapsa, Aphanothece, Chroococcus, Gloeocapsa, Gloeothece.*

The computer numbers for each species are those used in a recording system produced by B. M. Diaz, N. T. H. Holmes, M. K. Hughes and the authors. Further details of this system are available on request to the authors.

RESULTS

Taxonomic

The list of photosynthetic organisms found in pools is summarized in the next section. It consists entirely of algae with the exception of one aquatic monocotyledon, *Naias graminea*. A few other angiosperms were however occasionally partially submerged in transient pools, this being true especially of the (?) introduced herbs *Portulaca oleracea* and *Stachytarpheta jamaicensis* on West Island.

Algal species which are more typically terrestrial are included within the lists for some pools. This is because some rocks are alternatively submerged and exposed as the water level rises and falls during the wet season.

For convenience all items in the floristic list are termed species in this account, although in a few cases varieties are included, while in others several different forms have been lumped together.

Floristic list

MYXOPHYTA

010215 *Anabaena variabilis* Kütz. P, A.

010216 *A. ambigua* Rao. P. Widespread, and sometimes abundant, especially at the beginning of the wet season; later formed spores which dropped on to the bottom.

010531 *Aphanocapsa fusco-lutea* Hansg. > 1 ≤ 2 µm. P, El, A.

010532 *A. montana* Cramer. > 2 ≤ 4 µm. El, A.

010533 *A. grevillei* (Hass.) Rabenh. > 4 ≤ 6 µm. P, El, A.

010534 *A. roeseana* de Bary. > 6 ≤ 8 µm. P, El, A.

010535 *A. testacea* (A. Br.) Näg. > 8 µm. P, El, A.

010536 *A. delicatissima* W. et G. S. West. ≤ 1 µm. P, El, A.

010602 *Aphanothece pallida* (Kütz.) Rabenh. P, Ep.

010631 *Aphanothece saxicola* Näg. ≤ 2 µm. P, El, A.

010632 *A microspora* (Menegh.) Rabenh. > 2 ≤ 4 µm. P, En, El, A.

010902 *Calothrix braunii* Born. et Flah. Ep, A. Widespread, especially among floating flocs of other algae; at least probably just growth stage of *C. parietina*.

010905 *C. elenkinii* Kossinskaja. Ep.

010910 *C. marchica* Lemm. A.

010911 *C. parietina* Thuret. Ep. Main cover of most rocks in pools.

011302 *Chlorogloea microcystoides* Geitler. Ep.

011534 *Chroccoccus turgidus* (Kütz.) Näg. > 8 ≤ 16 µm, lamellate sheath. Ep, A. Widespread.

011538 *C. minutus* (Kütz.) Näg. > 4 ≤ 6 µm, non-lamellate sheath. P, El, A.

011539 *C. membranicus* (Menegh.) Näg. > 6 ≤ 8 µm, non-lamellate sheath. P, El, Ep, A.

011540 *C. turicensis* (Näg.) Hansg. > 8 ≤ 16 µm, non-lamellate sheath. P, El, Ep, A.

011541 *C. spelaeus* Ercegovic. > 16 ≤ 32 µm, non-lamellate sheath. P, El, Ep, A.

011811 *Cylindrospermum muscicola*. El, Ep, A.

011903 *Dactylococopsis raphidioides* Hansg. P. Rare; recorded only from West Is.

011904 *D. rupestris* Hansg. P. Recorded in only two pools. Abundant in CC11.

012201 *Entophysalis granulosa* Kütz. Ep.

013107 *Hapalosiphon welwitschii* W. et West. En, Ep.

012631 *Gloeocapsa montana* Kütz. > 2 ≤ 4 μm, sheath colourless. P, El, Ep, A.

012640 *G. dermochroa* Näg. > 2 ≤ 4 μm, sheath yellow-brown. P, El, Ep, A.

012641 *G. kutzingiana* Näg. > 4 ≤ 6 μm, sheath yellow-brown. P, El, Ep, A.

012642 *G. muralis* Kütz. > 6 ≤ 8 μm, sheath yellow-brown. P, El, Ep, A.

012647 *G. sanguinea* (Ag.) Kütz. > 4 ≤ 8 μm, sheath red-violet-blue. Ep. Predominantly terrestrial, but found occasionally in pools.

012731 *Gloeothece violacea* Rabenh. ≤ 2 μm. Ep.

012732 *G. palea* (Kütz) Rabenh. > 2 ≤ 4 μm. Ep, El, A.

012733 *G. repestris* (Lyngb.) Bornet > 4 ≤ 6 μm. Ep, El, A. Mainly restricted to terrestrial habitats, but occasional records for pools, where it can form macroscopic colonies overlying rocks.

012801 *Gloeotrichia echinulata* (J. E. Smith) P. Richter. Et.

012802 *G. ghosei* R. N. Singh. Et. Forms large brown lobed colonies on *Chara*.

012901 *Gomphosphaeria aponina* Kütz. P. Rare.

013313 *Homoeothrix varians* Geitler. Et. Frequent epiphyte on *Gongrosira*, and sometimes also on dead wood.

013601 *Hyella caespitosa* Born. et Flah. En.

013602 *H. fontana* Huber et Jadin. En. Especially abundant in pools W5 and W6.

013604 *H. balani* Lehmann. En.

013801 *Johannesbaptistia pellucida* (Dickie) Taylor et Drouet. P. Found only in the more brackish pools, where it sometimes formed large floating clumps.

014101 *Lithonema adriaticum* Erceg. En. Recorded only from W2.

014201 *Lyngbya aestuarii* Liebm. F, P. Very abundant in CC9

014202 *L. allorgei* Frémy. El, A.

014203 *L. aerugineo-coerulea* (Kütz.) Gom. F, El, A.

014204 *L. confervoides* Ag. F, P, A.

014205 *L. digueti* Gom. Fl, El, A. Widespread.

014206 *L. epiphytica* Hieron. Et. Frequently recorded epiphyte on *Plectonema gloeophilum* and *Oedogonium*.

014207 *L. hieronymusii* Lemm. F, P, El. Forms olive-green floating mats in pools in *Casuarina* Forest; eaten by *Cardisoma*.

014208 *L. kutzingii* Schmidle. Et. Occasional epiphyte on *Oedogonium*

014209 *L. limnetica* Lemm. F, P. Widespread.

014210 *L. majuscula* Harvey. F, Ep, El.

014211 *L. martensiana* Menegh. Ep, El, A. Widespread, and often abundant, either among other algae, or forming nearly unigal sheets.

014212 *Lyngbya nordgardhii* Wille. Ep. Widespread.

014214 *L. pusilla* (Rabh.) Hansg. Et. Frequent epiphyte of *Plectonema gloeophilum, Oedogonium* and *Pithophora*.

014215 *L. rigidula* (Kütz.) Hansg. Et. Frequent epiphyte of *Plectonema gloeophilum, Oedogonium* and *Pithophora*.

014231 *Lyngbya* sp., not above, ≤ 1 µm. El, A. Probably = *L. erebi* W. and G. S. West.

014232 *Lyngbya* sp., not above, $> 1 \leq 2$ µm. El, A.

014603 *Merismopedia trolleri* Bachmann. El. South Is. only.

014631 *M. minima* G. Beck. ≤ 1 µm. El. South Is. only.

014632 *M. tenuissima* Lemm. $> 1 \leq 2$ µm. El. South Is. only.

014633 *M. punctata* Meyen. $> 2 \leq 4$ µm. El. A record from pool W2 is only one for any species of this genus away from South Is.

014634 *M. glauca* (Ehrenb.) Näg. $> 4 \leq 6$ µm. El. South Is. only.

014707 *Microchaete tenera* Thuret. Ep. Generally rare, but large growths developed in the research station reservoirs and in the gutters of the solar stills.

014801 *Microcoleus chthonoplastes* Thuret. Ep, El.

014802 *M. sociatus* W. et G. S. West. Ep, El. Occasional, and never abundant.

014902 *Microcystis flos-aquae* (Wittr.) Kirchn. P. South Is. only, where it sometimes forms dense blooms.

015201 *Nostoc carneum* Ag. F, P. For most of the wet season present in only small amounts, but towards the end of wet season produced large floating colonies in some West Is. and Middle Is. pools.

015202 *N. commune* Vaucher. F, El. A species characteristic of depressions which receive frequent re-wetting and drying out during the wet season; not a typical component of vegetation of pools holding water for long periods.

015207 *N. microscopicum* Carm.

015210 *N. punctiforme* (Kütz.) Hariot. P, Ep, El, A. Occurs mostly on rocks in pools but occasionally also planktonic in the vicinity of *Chara* and *Naias*.

015213 *N. sphaericum* Vaucher. El. Forms characteristic spherical colonies up to 20 mm diameter in the Cinq Cases region; shallow depressions which have collected water may have their bottom almost covered with these colonies.

015218 *N. piscinale* Kütz. F, P, El, A.

015504 *Oscillatoria amphibia* Ag. El, A.

015505 *O. angusta* Koppe. El, A.

015506 *O. animalis* Ag. F, El, A. Often the first alga to appear when a pool is wetted, when it forms green sheets over the mud, which eventually rise as the pool deepens; eaten by *Cardisoma*.

015508 *O. brevis* (Kütz) Gom. F, El, A.

015509 *O. chalybea* (Mertens) Gom.

015510 *O. chlorina* Kütz. El, A.

015511 *O. claricentrosa* Gardner. El, A.

015514 *O. geminata* Menegh. El, A.

015517 *O. limosa* Ag. El, A.

015518 *O. mougeoti* Kütz. El, A.

015521 *O. proboscoidea* Gom. El, A.

015523 *O. pseudogeminata* Schmidle. El, A. Widespread, and recorded frequently throughout the wet season.

015538 *Oscillatoria* sp., > 32 μm. F, P, El. An exceptionally large form for *Oscillatoria;* although it was suspected of being a growth stage of *Lyngbya majuscula,* it was not possible to establish this. Restricted to South Island, and most abundant in the more brackish pools, where it forms sheets which lift of the bottom mud, and are eaten by *Cardisoma* and tortoises.

015585 *Oscillatoria tenuis* Ag. El, A.

015586 *O. acuta* Bruhl et Biswas. El, A.

015587 *O. acuminata* Gom. El, A.

015588 *O. acutissima* Kuff. El, A.

015589 *O. amphigranulata* Woronich. El, A.

015590 *O. guttulata* van Goor. El, A.

015591 *O. jasorvensis* Vouk. El, A.

015592 *O. koetlitzi* Fritsch. El, A.

015593 *O. lacustris* (Kleb.) Geitler. El, A.

015594 *O. limnetica* Lemm. F, El, A.

015595 *O. nigra* Vaucher. El, A.

015596 *O. obscura* Bruhl et Biswas. El, A.

015597 *O. okeni* Ag. El, A.

015598 *O. tambi* van Goor. El, A.

015701 *Phormidium africanum* Gom. Ep, A.

015704 *P. foveolarum* Gom. Ep, A.

015705 *P. hendersonii* Lemm. Ep, A.

015707 *P. jenkelianum* Schmidle. Ep, A.

015708 *P. mucicola* Huber-Pestalozzi et Naumann. Ep, A. Frequently present in the mucilage of other species.

015769 *P. bohneri* Schmidle. Ep, A.

015770 *P. corium* Gom. Ep, A.

015771 *P. molle* Gom. Ep, A.

015772 *P. usterii* Schmidle. Ep, A.

015773 *P. fragile* Ep, A.

015802 *Plectonema boryanum* Gom. F, Ep, A. Frequent both as epilith and forming a network of filaments among floating algae.

015806 *P. gloephilum* Borzi. F, Ep, El, A. Abundant, especially in West Is. pools where it often formed pink globular floating lumps which sometimes became the dominant alga.

015807 *P. gracillimum* (Zopf.) Hansg. F, Ep, El, A.

015815 *P. tomasinianum* Bornet. F, El.

015817 *P. notatum* Schmidle. Ep, El, A.

015818 *P. puteale* (Kirchn.) Hansg. Ep, El, A.

015901 *Pleurocapsa aurantiaca* Geitler. Ep, El, A.

015903 *P. amethystea* Kold. Ep, El, A. Recorded only from pool W1.

015931 *P. minor* Hansg. Ep, El, A. Widespread and often abundant.

016101 *Pseudanabaena catenata* Lauterb. El, A.

016103 *P. schmidlei* Jaag. El, A.

016104 *P. schmidlei* Jaag var. *gracilis* Skuja. El, A.

016301 *Radaisia cornua* Sauv. Ep.

016602 *Schizothrix arenaria* (Berk.) Gom. Ep. Occasional in pools on West Is., rare elsewhere.

016604 *S. calcicola* (Ag.) Gom. Ep.

016801 *Siphononema polonicum* Geitler. Ep. Only one record, from W2.

016901 *Spirulina subsalsa* Oerstd. El, A. Most abundant in South Is. pools, especially the more brackish ones where it sometimes became the dominant species.

016933 *Spirulina gigantea* Schmidle > 2 ≤ 4. μm.

017432 *Synechococcus cedrorum* Sauv. > 2 ≤ 4 μm. El, A.

017435 *S. aeruginosus* Näg. > 8 ≤ 16 μm. Ep, El, A.

017436 *S. maior* Schroeter. > 16 ≤ 32 μm. El, A.

017437 *S. maior* Schroeter var. *maximum* Elenkin et Hollerbach. > 32 μm.

017451 *Synechococcus* ≤ 2 μm. El, A.

017602 *Tolypothrix byssoidea* (Berk.) Kirchn. Ep. One of the main terrestrial algae of Aldabra: pool records probably in large part due to inwash of terrestrial material.

017606 *T. distorta* Kütz. Ep, El. A. Ocassional. Truly aquatic species.

017801 *Westiellopsis prolifica* Janet. Ep. Restricted to moist rock just above maximum water level of pools.

018033 *Xenococcus kerneri* Hansg. Et. Rare. Epiphyte of *Oedogonium* sp. and *Portulaca* sp.

018101 *Chroococcopsis gigantea* Geitler. Ep, A. Especially abundant in pool W2.

EUGLENOPHYTA

030201 *Euglena acus* Ehrb. P, El, A. A common species, especially on West Is.; dominant in W2 in the wet season.

030202 *E. gracilis* Klebs. P, El, A. One of the most widespread species on Aldabra.

030205 *E. spirogyra* Ehrb. P, El. Only 2 records, both from W2.

030206 *E. minuta* Presc. P, El, A. Widespread, but most abundant in West Is. pools.

030207 *Euglena oxyuris* Schmarda. P, El, A.

030249 *Euglena* spp., not above. P, El, A.

030401 *Lepocinclis ovum* (Ehrenb.) Lemm. P. Abundant in West Is. pools, rare elsewhere.

030501 *Phacus caudatus* Hüb

030502 *Phacus orbicularis* Hüb. P, El, A. One of the most widespread species, usually present throughout the wet season.

030601 *Trachelonomas hispida* (Perty) Stein emend. Deflandre var. *coronata* Lemm. P.

030602 *Trachelomonas volvocina* Ehrb. P. Formed nearly unialgal blooms in W5 and W6 for a short period, occasional records elsewhere.

CRYPTOPHYTA

049931 cryptomonad ≤ 8 μm long blue-green. P.

049932 cryptomonad, > 8 ≤ 16. μm long, blue-green. P.

049956 cryptomonad, > 16 ≤ 32 μm long, brown. P.

049959 cryptomonad, > 16 μm long, green. P.

PYRROPHYTA

059969 dinoflagellate A. P, Et. Occurs both as epiphyte on *Oedogonium* and free-living. Recorded only on West Is.

059970 dinoflagellate B. P. Recorded only towards end of wet season. Widespread, but never abundant.

XANTHOPHYTA

061150 *Goniochloris* sp. P.

062050 *Akanthochloris* sp. P, A.

CHRYSOPHYTA

081450 *Synura* sp. P. Rare.

BACILLARIOPHYTA

Centrales. Records for centric diatoms on South Is. only

090750 *Chaetoceros* sp.

099151 centric diatom ≤ 8 μm diameter. P, A.

099152 centric diatom > 8 ≤ 16 μm diameter. P, A.

Pennales

100250 *Amphora* spp. El, A. At least two distinct species.

101901 *Nitzschia acicularis* W. Smith. P, A. Only records from South Is.

101904 *N. palea* (Kütz.) W. Smith. P, El, A. By far the most widespread freshwater diatom.

109950 pennate diatom, other spp. P, El, A.

CONJUGATOPHYTA

120269 *Closterium* sp. A, F, El, A. Very abundant on West Is., where it forms conspicuous growths - less abundant on other islands.

120270 *Closterium* sp. B. F, El, A.

120271 *Closterium cynthia* De. Not. P, A.

120272 *Closterium* sp. D. P, A.

120369 *Cosmarium blyttii* Wille. P, A. Widespread, but not forming large populations. Present throughout wet season.

120370 *Cosmarium polygonum* (Näg.) Arch. P, A.

120306 *Cosmarium subcostatum* Nordst. P, A.

120372 *Cosmarium tinctum* Ralfs. P, A.

120373 *Cosmarium trachydermum* West and G. S. West. P, A.

121451 *Mougeotia* sp., *c.* 7 µm P. Only record in water-catchment drum, Middle Is.

122154 *Spirogyra* sp., $> 32 \leq 48$ µm, 1 chloroplast, non replicate. P, El. Found only on South Is.

122469 *Staurastrum polymorphum* Bréb. P, A.

122470 *Staurastrum* sp. B. P, A.

122471 *Staurastrum* sp. C. P, A.

122472 *Staurastrum* sp. D. P, A.

CHLOROPHYTA

Volvocales

130201 *Carteria globosa* Korshik. P. Recorded only for one pool near Anse Cédres.

130402 *Chlamydomonas globosa* Snow. P. Widespread, especially on West Is. and Middle Is.

130450 *Chlamydomonas* sp. P.

130901 *Eudorina elegans* Ehrb. P, A. Widespread, especially on West Is. and Middle Is.

131150 *Gonium* sp.

131601 *Phacotus lenticularis* (Ehrb.) Stein. P, A. Widespread and often abundant.

132601 *Pleodorina californica* Shaw. P. Only one record, from South Is.

Chlorococcales

140201 *Ankistrodesmus acicularis* (A. Br.) Korshik. P.

140205 *A. braunii* Brunnth. P.

140206 *A. falcatus* (Corda) Ralfs. P.

140207 *A. longissimus* Lemm. Wille. P.

140208 *A. minutissimus* Korshik. P. Occasionally the dominant species in the plankton. Maximum population recorded = 3.6×10^4 cells/ml on 5 Feb 1973 in pool W4.

140209 *A. mucosus* Korshik. P, A.

140210 *A. pseudomirabilis* Korshik. P. Often abundant.

140402 *Characium ornithocephalum* A. Br. Et. Rare.

140403 *Characium strictum* A. Br. Et. Rare, except for one sample from W5/W6.

140501 *Chlorella ellipsoidea* Gerneck P, A.

140504 *C. vulgaris* Beyer. P, A.

140508 *C. mucosa* Korshik. P, A.

141003 *Coelastrum cambricum* Arch. var. *rugosum* Rich. P.

141009 *Coelastrum microporum* Näg. P.

141501 *Dimorphococcus lunatus* A. Br. P. Recorded only on South Is., where it occasionally formed blooms.

142102 *Golenkinia radiata* Chod. P, A. Recorded only on South Is., where it is widespread.

142401 *Kentrosphaera bristolae* G. M. Smith. El, A.

142650 *Micractinium* sp. P.

231-339 O - '77 - 12

142750 *Nautococcus* sp. F, P. Forms distinctive yellow-green surface scums on some West Is. pools.

142902 *Oocystis crassa* Wittr. P, A.

142907 *O. parva* W. et G. S. West. P, A.

142910 *O. pusilla* Hansg. P, A.

143103 *Pediastrum boryanum* P, A.

143501 *Scenedesmus acuminatus* (Lag.) Chodat. P, A.

143501 *S. acuminatus* (Lag.) Chodat var. *biseriatus* Reinh. P, A.

143513 *S. bijugatus* (Turp.) Lagerheim. P, A. Widespread, and often quite abundant.

143513 *S. bijugatus* (Turp.) Lagerheim var. *alternans* (Reinsch) Hansg. P, A.

143508 *S. obliquus* (Turp.) Kütz. P, A.

143510 *S. quadricauda* (Turp.) Bréb. P, A.

143510 *S. quadricauda* (Turp.) Bréb. var. *abundans* Kirchn. P.

143510 *S. quadricauda* (Turp.) Bréb. var. *setosus* Kirchn. P, A.

144102 *Tetraedron incus* (Teil.) G. M. Smith. P, A.

144103 *T. minimum* (A. Br.) Hansg. P, A.

144104 *T. muticum* (A. Br.) Hansg. P, A.

144403 *Treubaria triappendiculata* Bern. P, A.

144605 *Lagerheimia genevensis* Chodat. P. Recorded only in Jan. 1969.

144703 *Sorastrum spinulosum* Näg. P.

Ulotrichales & Chaetophorales

150150 *Apatococcus* sp.

150250 *Aphanochaete* sp. Et.

151202 *Hormidium rivulare* Kütz. El.

152301 *Endoderma reineckei* Schmidle. Et. Almost restricted to being epiphytic on *Pithophora*.

152901 *Gongrosira debaryana* Rabh. Ep, El. Widespread, and usually abundant.

152949 *Gongrosira* sp. A. Ep, El.

154435 *Stichococcus bacillaris* Näg. Ep. Rare.

154603 *Trentepohlia iolithus* (L.) Wallr. Ep. Widespread. When pools dry down, this species is visually obvious as a pink or orange covering.

154604 *T. odorata* (Wiggers) Wittrock. Ep.

154734 *Ulothrix tenerrima* Kütz. Ep. El.

15995 Chaetophorales spp. other El.

160731 *Oedogonium* sp., < 8 μm. F, Ep, El, Et.

160732 *Oedogonium* sp., > 8 μm ≤ 12 μm. F, Ep, El, Et.

160733 *Oedogonium* sp., > 12 ≤ 16 μm. F, Ep, El, Et.

160734 *Oedogonium* sp., > 16 ≤ 20 μm. F, Ep, El, Et.

160801 *Pithophora oedogonia* (Mont.) Wittr. F, Et. Widespread, but seldom abundant. Sometimes used by White-eye as almost exclusive nest material.

161050 *Rhizoclonium* sp. F, Et.

CHAROPHYTA

170106 *Chara zeylanica* Kl. ex Willd. var. *diaphana* (Meyer) R. D. Wood

ANGIOSPERM

251602 *Naias graminea* Del.

Distribution within 20 pools also studied for water chemistry

The distribution of species within the 20 pools described by Donaldson and Whitton (1976) is shown in Table 1, while some of the observations on these pools are summarized in Table 2.

GENERAL OBSERVATIONS

Geographical

Some species were found only on West Is., while others only on South Is. The following are some examples:

West Is. (all restricted to only one or a few pools)
Gomphonema aponina (not var. *multiplex*), *Siphononema polonicum*, *Euglena spirogyra*, dinoflagellate A, *Akanthochloris* sp., *Characium ornithocephalum*, *C. strictum*.
South Is.
widespread species:
Microcystis flos-aquae, *Spirogyra* sp., *Staurastrum* spp., *Coelastrum cambricum*, *Dimorphococcus lunatus*, *Golenkinia radiata*, *Tetraedron incus*, *Naias graminea*
locally frequent or abundant species:
Gloeotrichia ghosei, *Nostoc sphaericum*, *Oscillatoria* sp. > 32 µm, *Chara zeylanica*
restricted to only one or a few pools:
Johannesbaptistia pellucida, cryptomonad (> 16 µm, long green), *Carteria globosa*.

In a few cases the reasons for the distribution of a species being restricted are fairly clear. For instance *Gloeotrichia ghosei* occurs only as an epiphyte on *Chara*, which latter has itself a restricted distribution. It is worth commenting that the first three species listed as restricted to West Is. were found only in W2, the most eutrophic of any pool studied on Aldabra. The four species listed as locally frequent or abundant all had the focus of their distribution in the region of CC9 (Bassin Flamant).

It is difficult to suggest any obvious factor of pool morphology or chemistry which might inhibit the spread to West Is. of some of the species widespread on South Is. *Microcystis* and *Spirogyra*, which are visually very obvious, were certainly quite absent from West Is. in both 1969 and 1973.

Seasonality

Examples of species which produced by far their largest crops early in the season are: *Oscillatoria animalis*, *Closterium* sp. A, *Eudorina elegans*, *Oedogonium* spp., *Pithophora oedogonia*. The *Pithophora* tended to form spores which dropped into the mud, and which presumably did not germinate until the pool dried out and became re-wetted. Examples of species which were evident only towards the end of the season are: *Gloeotrichia ghosei*, *Trachelomonas volvocina*, dinoflagellate B.

Influence of specific environmental factors on pool flora

(a) Pools which were intermittent rather than permanent through the wet season tended to have a relatively sparse flora, as is shown for W3, W10 and CC11 in Table 2. On the other hand the total surface area of the pool appears to have rather little influence on the richness of its flora, as can be seen by comparing Table 1 of Donaldson and Whitton (1976) with Table 2 of this paper. For example, W4, the pool for which the largest number of species were recorded, has a maximum surface area of only about 3.5 m^2.

Macroscopic colonies of *Nostoc* were almost always obvious in transient pools. Although these colonies occurred in various morphological forms, it seems probable that these may all be referred to one of the three binomials, *N. commune, N. microscopicum* and *N. sphaericum*. The other important algal components of such pools were mostly species of *Lyngbya, Phormidium* and *Plectonema*. Transient pools had few flagellates, and never became green with floating algal flocs on the surface.

(b) Although permanent throughout the 1972/73 wet season, two other pools, W102 and W103, both had a very restricted flora (Table 2). Both these pools were dominated throughout most of the period by blooms of *Euglena gracilis*.

(c) Several species were restricted to the more saline of the pools included in this survey e.g. *Johannesbaptistia pellucida, Spirulina subsalsa*.

Grazing

Planktonic algae sometimes showed a rapid fall in population density, and in some such cases observations strongly suggested that grazing by planktonic animals was responsible. For instance, the rapid development of a population of ostracods was probably responsible for the destruction of a dense *Ankistrodesmus falcatus* population in W2.

Larger algae were on many occasions observed to be eaten by crabs. For instance grazing by *Cardisoma carniflex* appeared to have a clear impact on the floating mats of *Oscillatoria animalis* which developed early in the season in W2, while this species was frequently observed to eat *Spirogyra* and *Chara* in the Bassin Flamant region. *Nostoc* colonies may possibly be less vulnerable to grazing by crabs than these other species, but *Cardisoma carniflex* was seen to eat *N. commune* in W10. *Geocrapsis stormi* was seen to eat *Oscillatoria animalis* and *Oedogonium* in W1.

As already noted by Grubb (1971) tortoises also often eat some of the larger algae. This occurred for instance, with the flocs of *Oscillatoria* sp. > 32 µm and *Spirogyra* in CC5 and CC10. During observations made on CC10 throughout one day it became clear that tortoise grazing had an obvious impact on growths of both species. Tortoises were not seen to eat *Nostoc* colonies, though these were often readily available.

Comparison of 1968/69 observations with 1972/73 observations

Although most of the observations reported in this paper were made during the 1972/73 survey floristic notes were also made during the 1968/69 survey. The former survey was much less extensive both in time and in number of pools studied, and only about half the number of species listed for 1972/73 were found in 1968/69. Three species were recorded only in the earlier survey: *Wollea bharadwajae*, ?*Lobomonas* sp., *Lagerheimia genevensis*. (Of these, the material recorded as *Wollea*

bharadwajae may possibly have been only a form of *Anabaena ambigua* growing in the Cinq Cases region).

Pools W1, T1 and T2 were studied in both surveys, and the floras recorded in both surveys tended to be rather similar. In T1, five species were recorded in the two samplings made in 1968/69 but not in the three of 1972/73, while 11 species were recorded in 1972/73 but not 1968/69. However almost as many differences were recorded between indvidual surveys made within either of the two seasons.

ACKNOWLEDGEMENTS

We are most grateful to the Royal Society and the Natural Environment Research Council for financial support, and to Mrs. V. Evans for typing this paper.

REFERENCES

Desikachary, T. V. 1959. *Cyanophyta.* Indian Council Agricultural Research.

Donaldson, A. and Whitton, B. A. 1976. Chemistry of freshwater pools on Aldabra Atoll. *Atoll Research Bulletin,* this issue.

Geitler, L. 1932. Cyanophyceae. In: *Rabenhorst's Kryptogamen-Flora,* Vol. 14. Akademische Verlagsgesellschaft, Leipzig.

Golubić, S. 1967. Algenvegetation der Felsen. Ein ökologische Algenstudie im dinarischen Karstgebiet. *Die Binnengewässer* 23: 1-183. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, Germany.

Grubb, P. 1971. The growth, ecology and population structure of giant tortoises on Aladabra. *Phil. Trans. R. Soc.* B 260: 327-372.

McKenzie, K. G. 1971. Entomostraca of Aldabra, with special reference to the genus *Heterocypris* (Crustacea, Ostracoda). *Phil. Trans. R. Soc.* B 260: 257-298.

Starmach, K. 1966. Cyanophyta-Sinice, Glaucophyta-Glaukofity (Polish). *Flora slodkowodna Polski,* Pol. Acad. Sci. 2; 1-807.

Table 1. Distribution of photosynthetic organisms in the 20 freshwater pools included within water chemistry survey

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Anabaena variabilis	+											+		+	+	+	+			+	7
A. ambigua	+			+								+		+	+	+	+			+	8
Aphanocapsa fusco-lutea	+	+		+	+	+	+										+				7
A. montana	+	+	+	+	+			+	+				+					+			9
A. grevillei	+		+	+			+	+	+				+	+	+	+		+		+	12
A. roeseana	+			+		+	+	+					+	+			+			+	9
A. delicatissima			+				+											+			3
Aphanothece saxicola	+															+	+				3
A. microspora	+			+									+	+	+						5
A. microscopica	+		+			+	+	+			+			+	+						8
Calothrix braunii	+		+	+	+		+	+	+				+		+	+				+	11
C. elenkinii														+		+					2
C. marchica				+		+	+	+		+			+		+						7
C. parietina	+	+	+	+	+	+	+		+		+	+	+	+	+	+				+	15
Chlorogloea microcystoides	+			+																	2
Chroococcus turgidus	+	+							+				+	+	+					+	7
C. minutus	+			+			+	+									+			+	6
C. membranicus	+			+			+	+						+			+			+	7
C. turicensis			+	+								+	+	+							5
C. spelaeus				+																	1
Dactylococcopsis raphodioides		+			+	+															3
C. rupestris	+																		+		2
Entophysalis granulosa	+						+	+								+		+			5
Hapalosiphon welwitschii	+	+		+			+	+	+												6
Gloeocapsa montana	+			+																	2
G. dermochroa		+		+																	2
G. kutzingiana		+		+																	2
G. muralis				+																	1
G. sanguinea	+	+	+	+	+	+	+	+	+												9
G. rupestris	+						+	+							+						4
Gloeotrichia ghosei																	+				1
Gomphosphaeria aponina		+																			1
Homoeothrix varians		+			+	+	+	+			+	+				+		+		+	10

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Hyella caespitosa																		+			1
H. fontana	+	+		+	+	+	+	+				+	+	+	+					+	12
Johannesbaptistia pellucida																	+				1
Lithonema adriaticum		+																			1
Lyngbya aestuarii																	+				1
L. allorgei	+	+			+		+						+	+			+				7
L. aerugineo-coerulea					+																1
L. confervoides														+	+		+			+	4
L. digueti	+	+	+	+	+	+	+	+		+			+	+				+			12
L. epiphytica	+		+	+	+																4
L. hieronymusii				+		+	+						+		+						5
L. kutzingii					+																1
L. limnetica			+	+	+	+	+														5
L. martensiana														+	+		+	+	+		5
L. nordgardhii	+	+		+	+	+	+	+	+			+	+		+	+		+		+	14
L. pusilla	+	+		+			+	+	+			+					+				8
L. rigidula	+			+	+	+	+		+												6
Lyngbya sp., not above, < 1 µm	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	20
Lyngbya sp., not above, > 1 ≤ 2 µm	+			+		+															3
Merismopedia trolleri												+									1
M. tenuissima													+		+						2
M. punctata		+										+		+	+		+			+	6
M. glauca													+		+		+				3
Microcoleus chthonoplastes	+														+						2
M. sociatus							+														1
Microcystis flos-aquae														+	+	+	+			+	5
Nostoc carneum	+					+															2
N. commune			+						+			+			+						4
N. microscopicum	+		+						+			+									4
N. punctiforme	+	+		+		+	+					+				+	+			+	9
N. spaericum																			+		1
N. piscinale						+															1
Oscillatoria amphibia														+							1
O. angusta		+			+	+	+	+		+	+			+	+		+				10

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
O. animalis	+	+		+	+	+	+	+	+				+		+		+	+			12
O. chlorina				+			+	+					+								4
O. claricentrosa															+						1
O. geminata	+											+	+								3
O. limosa				+			+	+									+				4
O. mougeotii			+				+								+						3
O. proboscoidea													+								1
O. pseudogeminata	+	+	+	+	+	+	+	+	+	+		+	+		+					+	14
O. subtilissima												+					+				2
O. tenuis	+			+		+							+		+		+				6
O. amphigranulata		+				+	+							+							4
O. brevis		+		+	+	+	+	+		+				+			+				9
O. gluttulata													+								1
O. koetlitzi												+									1
O. lacustris															+						1
O. limnetica												+									1
O. obscura																	+				1
O. tambi			+																		1
Oscillatoria sp. > 32 µm																	+	+		+	3
Phormidium africanum													+								1
P. foveolarum	+	+		+																	3
P. hendersonii	+					+		+				+			+			+		+	7
P. jenkelianum	+		+	+	+				+											+	6
P. mucicola	+		+	+	+	+	+	+	+				+	+	+	+		+	+	+	15
P. bohneri		+		+	+	+		+	+												6
P. corium				+																	1
P. molle	+	+			+								+								4
P. usterii				+																	1
P. fragile	+	+	+	+	+	+	+		+			+	+	+			+	+		+	14
Plectonema boryanum				+				+				+							+	+	5
P. gloeophilum	+		+	+		+	+	+	+	+											8
P. gracillimum	+			+										+			+	+		+	6
P. notatum									+												1
P. puteale																	+				1

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1'	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Pleurocapsa auranticaca	+																				1
P. amethystea	+																				1
P. minor	+	+	+	+	+	+	+	+	+	+		+	+		+			+		+	15
Pseudanabaena catenata	+			+								+	+		+		+			+	7
P. schmidlei			+	+																	2
P. schmidlei var. gracilis				+																	1
Radaisia cornua		+			+																2
Schizothrix arenaria				+			+														2
S. calcicola				+																	1
Siphononema polonicum		+																			1
Spirulina subsalsa														+	+		+			+	4
Synechococcus cedrorum		+		+								+									3
S. aeruginosus	+								+	+					+		+				5
S. maior					+	+											+				3
Synechococcus ≤ 2 µm													+								1
Tolupothrix byssoidea	+	+	+	+	+		+	+	+				+		+						10
T. distorta								+							+						2
Westiellopsis prolifica	+				+																2
Xenoccoccus kerneri				+																	1
Chroococcopsis gigantea	+	+		+																	3

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Euglena acus	+	+													+						3
E. gracilis	+	+	+	+	+		+	+		+	+	+					+			+	12
E. spirogyra		+																			1
E. minuta		+			+	+	+	+			+	+					+				8
E. oxyuris					+	+					+										3
E. spp. not above					+									+							2
Lepocinclis ovum					+	+	+														3
Phacus orbicularis	+	+		+	+	+	+	+		+	+	+	+	+						+	13
Trachelomonas volvocina				+	+	+															3
cryptomonad > 8 ≤ 16 μm long, blue-green		+			+		+	+													4
cryptomonad > 16 ≤ 32 μm long, brown														+						+	2
cryptomonad > 16 μm long, green												+									1
dinoflagellate A.	+			+		+															3
dinoflagellate B.	+		+	+	+	+											+				6
Akanthochloris sp.	+				+	+		+													4
centric diatom ≤ 8 μm diameter													+							+	2
Amphora sp. B																	+			+	2
Nitzschia palea				+	+		+	+		+		+	+	+	+		+	+		+	12
pennate diatom, other spp.										+		+	+	+		+	+				6
Closterium lanceolatum	+	+		+	+	+	+	+		+		+									9
Closterium sp. B.	+			+		+	+														4
Closterium sp. D.															+		+			+	3
Cosmarium blyttii	+			+		+						+			+					+	6
Cosmarium polygonum															+		+		+	+	4
Cosmarium subcostatum															+		+		+	+	4
Cosmarium tinctum																	+				1
Cosmarium trachydermum																	+				1
Spirogyra > 32 ≤ 48 μm, 1 chloroplast, non-replicate												+			+			+			3
Staurastrum polymorphum															+					+	2
Staurastrum sp. B.															+						1
Chlamydomonas globosa		+	+		+	+	+	+		+											7
Chlamydomonas spp., other		+	+		+	+	+		+												6
Eudorina elegans	+			+		+	+	+				+			+						7

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Phacotus lenticularis				+	+		+	+				+			+				+	+	8
Ankistrodesmus acicularis		+		+			+					+	+				+				6
A. braunii	+	+		+	+	+	+	+		+	+										9
A. falcatus		+		+		+	+						+				+			+	7
A. longissimus		+																			1
A. minutissimus	+	+		+		+	+					+	+								7
A. pseudomirabilis				+			+								+		+			+	5
Characium ornithocephalum				+																	1
C. strictum			+		+																2
Chlorella ellipsoidea	+	+																			2
C. vulgaris	+		+		+	+	+	+													6
C. mucosa		+																			1
Coelastrum cambricum var. *rugosum*														+	+						2
C. microporum		+										+	+	+	+					+	6
Dimorphococcus lunatus												+			+						2
Golenkinia radiata												+		+	+	+	+			+	6
Kentrosphaera bristolae	+				+	+	+	+													5
Nautococcus sp.	+			+	+	+	+													+	6
Oocystis crassa					+												+				2
O. parva	+			+			+								+					+	5
O. pusilla	+			+																	2
Scenedesmus acuminatus														+	+					+	3
S. acuminatus var. *biseriatus*															+						1
S. bijugatus	+			+			+	+			+			+	+						7
S. bijugatus var. *alternans*															+						1
S. obliquus															+						1
S. quadricauda		+		+			+					+	+	+	+	+	+			+	10
S. quadricauda var. *abundans*															+						1
S. quadricauda var. *setosus*		+		+			+	+			+	+	+								7
Tetraedron incus												+	+		+		+		+		5
T. minimum												+			+					+	3
T. muticum				+			+					+					+				4

	W1	W2	W3	W4	W5	W6	W7	W9	W10	W102	W103	T1	T2	CC2	CC5	CC8	CC9	CC10	CC11	CC12	Total
Treubaria triappendiculata														+	+						2
Endoderma reineckei				+			+	+			+			+		+					6
Gongrosira debaryana	+	+	+	+	+	+	+	+		+	+					+					11
Gongrosira sp. A.											+			+			+	+	+	+	6
Trentepohlia iolithus	+			+												+					3
Oedogonium sp. ≤ 8 µm	+			+			+								+			+	+		6
Oedogonium sp. > 8 ≤ 12 µm	+			+			+					+		+	+	+				+	8
Oedogonium sp. > 12 ≤ 16 µm	+			+			+					+									4
Oedogonium sp. > 16 ≤ 20 µm	+			+																	2
Pithophora oedogonia				+			+	+			+			+		+					6
Chara zeylanica															+		+			+	3
Naias graminea												+			+		+			+	4

Table 2. Summary of data concerning distribution of algae within the 20 pools chosen for most detailed study.

pool	total species	total Myxophyta	total eukaryotes	% Myxophyta	in only this pool out of the 20	in only this pool on island	spp. in plankton only	spp. epiliths only	total heterocystous spp.	heterocystous plankton spp.
W1	79	54	25	69	2	2	5	8	10	5
W2	55	35	20	64	6	3	11	7	3	1
W3	31	24	7	78	1	0	3	3	3	0
W4	86	56	30	65	7	1	7	7	7	4
W5	53	31	22	59	3	0	7	7	4	1
W6	53	32	21	61	1	0	7	2	4	4
W7	70	39	31	56	0	0	9	7	6	3
W9	52	34	18	68	1	0	3	5	4	3
W10	24	23	1	96	0	0	1	4	5	1
W102	17	9	8	53	0	0	2	0	3	1
W103	16	5	11	31	0	0	1	1	1	0
T1	44	22	22	50	4	1	6	2	6	3
T2	43	32	11	74	3	0	3	3	4	0
CC2	43	27	16	63	2	0	5	2	4	2
CC5	67	37	30	56	9	1	6	3	10	5
CC8	22	14	8	64	0	0	1	2	6	4
CC9	56	35	21	62	6	1	4	1	4	4
CC10	21	17	4	81	0	0	0	1	0	0
CC11	13	7	6	54	1	0	0	0	2	1
CC12	51	28	23	55	0	0	5	2	3	3

ATOLL RESEARCH BULLETIN
NO. 216

TERRESTRIAL AND FRESHWATER ALGAE OF THREE WESTERN INDIAN OCEAN ISLANDS (ASTOVE, FARQUHAR AND ST. PIERRE)

by B. A. Whitton and A. Donaldson

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

TERRESTRIAL AND FRESHWATER ALGAE OF THREE WESTERN INDIAN OCEAN ISLANDS (ASTOVE, FARQUHAR AND ST. PIERRE)

by B. A. Whitton and A. Donaldson [1]

Introduction

In contrast to the many studies of the marine algae of tropical limestone islands, the terrestrial and freshwater algae have received little attention. A preliminary account for Aldabra (Whitton, 1969) is apparently the only description of such algae from the Western Indian Ocean. This account emphasized the abundance of blue-green algae, and it was suggested that these might be of considerable ecological significance. The following note provides comparative observations made during brief visits (by B.A.W.) to Astove (10°6'S, 47°45'E), Farquhar Atoll (10°11'S) and St. Pierre (9°19'S, 50°43'E during March - April 1973.

The ecology and vascular plant species of Astove and Farquhar Atoll have recently been described in some detail (Astove: Bayne *et al.*, 1970; Fosberg & Renvoize, 1970b; Farquhar Atoll: Stoddart & Poore, 1970; Fosberg & Renvoize, 1970a), while the data known for St. Pierre have been summarized by Vesey-Fitzgerald (1942), Stoddart (1967) and Piggott (1969). The reader is referred to these accounts for general environmental information. Samples were either studied while still fresh, or dried down and re-wetted before viewing. In addition a few samples from each island were used as a source of inocula for subsequent growth in the laboratory using a range of media.

Observations

As the visits to each of these islands lasted only a few hours, the accounts are obviously very incomplete. Nevertheless it was rapidly obvious that while all three islands resembled Aldabra (Whitton, 1969) in having blue-green algae constituting the bulk of the algal vegetation, the overall abundance varied markedly between them, being most abundant on St. Pierre and least abundant on Farquhar. The species records are summarized in Table I.

---

[1] Department of Botany, University of Durham, Durham, England

(Manuscript received June 1974--Eds.)

231-339 O - '77 - 13

Astove

(Visited 3 April 1973). The algal vegetation of the western side of this elevated atoll (the only region visited) rather closely resembled that of West Island, Aldabra. The rocks had a general cover of *Tolypothrix byssoidea,* with *Gloeocapsa sanguinea* almost always closely associated with it. *Tolypothrix byssoidea* also sometimes formed small black patches on bare sand, and in such cases the principal alga associated with it was *Schizothrix arenaria.* Conspicuous growths of (typical) *Nostoc commune* colonies were sometimes present on the limestone, while *N. commune* var. *flagelliforme* was frequent in the coconut plantations. Small freshwater pools were quite common, especially towards the lagoon. These were mostly 2-4 m diameter and reached (at the time of visit) up to 0.6 m deep. These had an attached algal cover, a plankton, and usually also a partial surface cover of flocs or filaments buoyant as a result of associated oxygen bubbles. Species almost always present at the sides of these pools included: *Calothrix parietina, Lyngbya* spp., *Gongrosira* sp. and *Oedogonium* sp. The plankton consisted of varying proportions of blue-green algae (including *Anabaena variabilis, Phacotus lenticularis, Chlorella* sp., *Scenedesmus quadricauda, Tetraedron minimum* and *Euglena* sp. Floating flocs mostly consisted of *Closterium* sp., *Oedogonium* sp., *Spirogyra* sp.

Only one species was recorded on Astove which has so far (the authors, unpublished) not been found on Aldabra. This was *Stigonema hormoides,* which was locally frequent in an area about 1 km south of the settlement, occuring on shaded concavities on rocks. As this species is easily visible to the naked eye, and relatively distinctive, its presence on Astove may represent a genuine difference from Aldabra.

Farquhar Atoll

(Visited 16 March and 6 April 1973; North Island only). The algal vegetation was relatively inconspicuous. This was no doubt largely due to the general cover of coconut trees over most of the island, and to the rarity of standing freshwater. Nevertheless it seems possible that these are not the only explanations since typical *Nostoc commune* colonies were not recorded anywhere, and *N. commune* var. *flagelliforme* occurred only very rarely. Exposed rock surfaces did however resemble those of Astove in having a thin cover of *Tolypothrix byssoidea* and *Gloeocapsa sanguinea.*

One small area of freshwater was found, apparently identical with the marshy area referred to by Stoddart and Poore (1970, p.16). Its general appearance and algal species composition was rather similar to that of a saline pool, so it seems possible that it may not remain freshwater throughout the year. This pool overlay a dark-coloured fine silt, and lacked exposed rock surfaces. The only algae found were blue-green algae, these mostly occurring as floating granules or mucilaginous lumps. Such flocs taken from deeper layers in the pool contained many purple photosynthetic bacteria, which together with some forms of *Aphanocapsa* were often sufficient to colour the granules pink. The blue-green algae included: *Aphanocopsa* spp., *Chroococcus minutus, Synechococcus*

elongatus, Lyngbya spp.

St. Pierre

(Visited 17 March 1973). This island is sufficiently small (417 acres) for an impression of the whole area to have been obtained during the visit, which occurred a year after mining for guano had finally been completed.

Observations on the algal flora of St. Pierre are of particular interest in view of the high levels of phosphate likely still to be available in many microhabitats. In spite of the large literature published in recent years on the effect of phosphate eutrophication in freshwaters, there have been no previous accounts of the algae of naturally occurring very phosphate-rich environments.

At the time of the visit there was much standing water, with hundreds of small freshwater pools. About one-sixth of the island is covered with young trees of *Casuarina* (up to 4m high). In addition there were about 20 much older trees of this species and 5 coconut palms. The open part of the island is deeply dissected by thousands of crevices. The solitary *Pisonia grandis* found in 1960 by Piggott (1969) is apparently dead, and the angiosperm vegetation of this region consisted of *Ipomoea* and various herbs, especially *Stachytarpheta jamaicensis, Turnera ulmifolia, Vernonia cinerea* and *Lippia nodiflora* (all names based on field observations only).

Both blue-green algae and lichens were very conspicuous. As with the other islands, the more exposed parts of the rock were dominated by *Tolypothrix byssoidea*. Epilithic lichens were much more abundant here than on any of the other islands (including Aldabra). Crustose lichens were especially abundant on the lips of the rocks adjacent to fissures. Small blue-green alga containing lichens were also often evident, especially where the covering of free-living epilithic blue-green algae was particularly thick. Recent observations have shown that the latter phenomenon occurs also on Aldabra.

No large *Nostoc commune* colonies were seen, but a thin film of *Nostoc* was common in rock concavities. The small pools were sometimes completely filled by growths of *Rhizoclonium,* mixed with numerous small blue-green algal colonies. In the young *Casuarina* woodland, *Oscillatoria animalis* was abundant. Samples from this region cultured on agar with mineral medium developed, in addition to algal colonies, a particularly rapid and vigorous growth of actinomycetes.

Discussion

Although Table I is merely a preliminary list of the algal floras of these atolls, nevertheless they probably give a fair indication of the relative proportions of the main algal groups represented. Blue-green algae are by far the most important group, and free-living eukaryotic algae are largely restricted to the pools. *Tolypothrix*

byssoidea was the most widespread alga on all three islands, being ubiquitous on rocks and widespread on sand. This species has a similar distribution both on Aldabra (the authors, unpublished) and the Bikini islands (Taylor, 1950). The Indian Ocean islands do however show a marked contrast to the latter in that neither *Porphyrosiphon* nor *Symploca* have so far been found on them, whereas Taylor reports them to be major constituents of the vegetation of sand on Bikini.

Acknowledgements

This survey was carried out while the authors were in receipt of a grant from the Royal Society and Natural Environment Research Council for research on Aldabra. The authors are most grateful to both these bodies and to Dr. D. R. Stoddart for a guide to the literature about St. Pierre.

TABLE 1. Terrestrial and freshwater algal floras

	Astove	Farquhar	St. Pierre
MYXOPHYTA			
Chroococcales			
Aphanocapsa fusco-lutea Hansg.	+	+	+
A. grevillei (Hass.) Rabenh.			+
A. muscicola (Menegh.) Wille	+	+	+
Aphanothece castagneii (Bréb.) Rabenh.			+
A. pallida (Kütz.) Rabenh.	+	+	+
Gloeocapsa magma (Bréb.) Hollerbach. emend.	+		+
G. sanguinea (Ag.) Kütz.	+	+	+
Gloeothece rupestris (Lyngbye) Barnet			+
Chroococcus minutus (Kütz.) Näg.		+	
C. turgidus (Kütz.) Näg.	+	+	+
C. turicensis (Näg.) Hansg.	+	+	+
Synechococcus aeruginosus Näg.			+
S. elongatus Näg.			
Chamaesiphonales			
Pleurocapsa minor Hansg. em. Geitler		+	+
Hyella fontana Huber et Jadin	+		+
Hormogonales			
Hapalosiphon welwitschii W. et G.S. West			+
Westiellopsis prolifica Janet	+	+	+
Stigonema hormoides (Kütz.) Born. et Flah.	+		+
Calothrix marchica Lemm.	+		+
C. parietina Thuret	+		
Gloeotrichia sp.			+
Microchaete tenera Thuret			+
Plectonema boryanum Gomont	+	+	+
P. gloeophilum Borzi		+	
P. gracillimum (Zopf.) Hansg.			+
P. notatum Schmidle		+	
P. terebrans Born. et Flah.			+
Tolypothrix byssoidea (Hass.) Kirchn.	+	+	+
T. tenuis Kütz	+	+	+
Cylindrospermum muscicola Kütz.			+
Nostoc carneum Ag.	+	+	+
N. commune Vaucher	+	+	+
N. commune Vaucher var. *flagelliforme* (Berk et Curtis) Born. et Flah.	+	+	
N. microscopicum Carm. sec. Harvey, in Hook	+	+	+

TABLE 1. (Cont.)

	Astove	Farquhar	St. Pierre
N. paludosum Kütz.			+
N. piscinale Kütz.	+	+	+
N. punctiforme (Kütz.) Hariot	+	+	+
N. piscinale Kütz.	+	+	+
N. sphaericum Vaucher			+
Anabaena variabilis Kütz	+		+
Oscillatoria animalis Ag.	+		+
O. pseudogeminata G. Schmid			+
O. tenuis Ag.			+
Phormidium africanum Lemm.			+
P. angustissimum W. et G. S. West			+
P. tenue	+		+
Lyngbya allorgei Frémy	+	+	+
L. digueti Gom.	+	+	+
L. erebi W. et G. S. West		+	+
L. martensiana Menegh	+		+
L. nordgardhii Wille			+
L. perelegans Lemm	+		
Schizothrix arenaria (Berk.) Gom	+		
S. calcicola (Ag.) Gom			+
CONJUGATOPHYTA			
Spirogyra sp.	+		
Closterium sp.	+		
Cosmarium subcostatum Nordst.	+		+
Cosmarium sp.	+		
CHLOROPHYTA			
Phacotus lenticularis (Ehr.) Stein	+		+
Ankistrodesmus minutissimus Korschik.	+		
Chlorella sp.	+		
Scenedesmus quadricauda (Turp.) Bréb.	+		
Tetraedron minimum (A.Br.) Hansg.	+		
Gongrosira sp.	+		+
Trentepohlia iolithus (L.) Wallroth			+
Oedogonium sp. (? p.)	+		+
Rhizoclonium sp. *c.* 40 µm broad	+		
EUGLENOPHYTA			
Euglena sp. *c.* 30 µm long	+		
Euglena sp. *c.* 75 µm long	+		
XANTHOPHYTA			
Akanthochloris sp.			+

TABLE 1. (Cont.)

	Astove	Farquhar	St. Pierre
BACILLARIOPHYTA			
Nitzschia palea (Kütz.) W. Smith	+		
Nitzschia sp.	+		
Total	43	23	51

References

Bayne, C. J., Cogan, B.H., Diamond, A. W., Frazier, J., Grubb, P., Hutson, A., Poore, M. E. D., Stoddart, D. R. and Taylor, J. D. 1970 Geography and ecology of Astove. *Atoll. Res. Bull.* 136: 83-99.

Desikachary, T. V. 1959 *Cyanophyta.* 686 pp. Indian Council of Agricultural Research, New Delhi, India.

Fosberg, F. R. and Renvoize, S. A. 1970a Plants of Farquhar Atoll. *Atoll Res. Bull.* 136: 27-33.

Fosberg, F. R. and Renvoize, S. A. 1970b Plants of Astove Island. *Atoll Res. Bull.* 136: 101-111.

Geitler, L. 1932 Cyanophyceae. In: *Rabenhorst's Kryptogamen-Flora,* Vol. 14. Akademische Verlagsgesellschaft, Leipzig.

Piggott, C. J. 1969 *A Report on a Visit to the Outer Islands of Seychelles between October and November 1960.* Land Resources Division of Overseas Surveys, Tolworth, Surrey, England.

Stoddart, D. R. 1967 Summary of the ecology of coral islands north of Madagascar (excluding Aldabra). *Atoll Res. Bull.* 118: 53-61.

Stoddart, D. R. and Poore, M. E. D. 1970 Geography and ecology of Farquhar Atoll. *Atoll Res. Bull.* 136: 7-26.

Taylor, W. R. 1950 *Plants of Bikini and other northern Marshall Islands.* Ann Arbor, Michigan: University Press.

Vesey-Fitzgerald, L. D. E. F. 1942 Further studies on the vegetation on islands in the Indian Ocean. *J. Ecol.* 30: 1-16.

Whitton, B. A. 1969 Terrestrial and freshwater algae of Aldabra. *Phil. Trans. R. Soc. Lond.* B. 260: 249-255.

ATOLL RESEARCH BULLETIN
NO. 217

TERRESTRIAL AND SWAMP ALGAE FROM THREE ISLANDS IN THE CHAGOS ARCHIPELAGO, INDIAN OCEAN

by B. A. Whitton, A. Donaldson, D. J. Bellamy and C. Sheppard

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

TERRESTRIAL AND SWAMP ALGAE FROM THREE ISLANDS IN THE CHAGOS ARCHIPELAGO, INDIAN OCEAN

by B. A. Whitton, A. Donaldson, D. J. Bellamy and C. Sheppard [1]

INTRODUCTION

During visits to the Chagos group of islands by two of the authors (D. J. B. in January 1973; D. J. B., C. S. from January to March 1975), several collections were made of conspicuous algal growths from terrestrial and swamp habitats. As these growths provide some interesting similarities and differences from those reported previously from other islands in the Indian Ocean (Donaldson & Whitton, 1976; Whitton & Donaldson, 1976), a brief account of their floristic composition is given here.

The Chagos Islands (6°S, 71°W) form part of the British Indian Ocean Territory. The samples described here were taken from three of these islands, Egmont, Eagle and Danger. Egmont Is. is one of the atolls which lie around the periphery of the Chagos archipelago, while Eagle Is. and Danger Is. may be considered as being part of the rim of a very large former atoll, now almost entirely submerged. No rainfall records exist for any of these three islands, but stations have at times existed on three of the other peripheral islands, Diego Garcia, Salòmon Is. and Peros Banhos, the most recent being those from Peros Banhos. Here it is estimated that during 1950-1966 there occurred a mean annual rainfall of 3999 mm (Stoddart, 1971). Seasonal changes in precipitation were relatively small, with the lowest values being in May and June.

METHODS

Samples were dried soon after collection and then sealed in individual packets. They were viewed after re-wetting with distilled water. In certain cases simple cultural techniques were used either to help confirm identifications or to demonstrate the presence of further species. Species noted only after culture are noted below.

---

[1] Department of Botany, University of Durham, Durham, England.
(Manuscript received 8 July 1975 --Eds.)

The species categories used in the various tables of results are based on these used in an algal computer recording system held at Durham, and described further in Donaldson and Whitton (1976). The size ranges given are standard ranges used in our system; the full range of these widths have not necessarily been found in these samples from the Chagos Is.

RESULTS

Eagle Is.

Almost 50 different samples were collected here during 1975. Three quite different types of algal community were represented, two from clearings in the coconut plantations, and two from *Typha* swamp regions. Their species compositions are compared in Table 3.

A. Thin olive-brown sheets spreading across debris overlying sand in a clearing; dominated by *Nostoc commune*.

B. Flattened to hemispherical lumps, reaching a maximum height of 9 mm, lying over grey or pale brown sand in coconut clearings; frequent. The main blue-green algal layer is only 1 mm thick, the remainder of the lumps being largely filled with sand. However there is usually a zone about 2 mm thick below the main blue-green algal layer which has a faint green tinge, this being due to moss protonema and *Lyngbya martensiana*. Some of the filaments of *Tolypothrix byssoidea* are moderately calcified, while those of *Lyngbya martensiana* and *Schizothrix arenaria* are also sometimes calcified.

C. Algal layer forming patches in more or less open areas within a swamp community dominated by *Typha* sp. and *Eleocharis* sp. These algal layers are probably completely submerged after heavy rainfall, but at the time of collection formed a dark grey slimy layer overlying a dark humus; moss shoots are also mixed with the algal layer. On drying out, the algal layer turns to a grey-green colour, as a result of the highly calcified layer around the sheaths of the dominant alga, *Tolypothrix byssoidea*.

D. ± Continuous layer of blue-green algae overlying dense brown fibrous mass, near a mangrove swamp. Algal layer about 3 mm thick, gelatinous, crumbly, irregular on surface. Obvious vertical zonation (Table 4). Some, but not all, of the dominant alga, *Tolypothrix byssoidea*, is calcified.

Egmont

Samples of mat were taken from a barachois community both in 1973 and 1975. The water associated with this community presumably varies considerably in salinity according to the pattern of rainfall in the previous few weeks; at the time of study in 1975 it was slightly brackish (Na, 236 mg l^{-1}).

The detailed composition of the mat is somewhat variable, but always had a layer dominated by Oscillatoriaceae overlying a layer of purple photosynthetic bacteria. The single sample of mat returned in 1973 was much thicker than any of the 10 samples returned in 1975, the photosynthetic layer reaching a depth of 10 mm and with obvious vertical zonations of the various blue-green algae present. Details of this mat profile are summarized in Table 1. The composition of this mat rather closely resembles one already described for rock pools on the Florida Keys, U.S.A., even though these latter are intertidal (Fischer and Golubić, in Ginsburg, 1967) and termed by Golubić (1973) a 'stratified community mat in intertidal rock pool'.

The samples returned in 1975 were much thinner, with the blue-green algal layer about 3-4 mm thick. A consolidated species list is given in Table 2.

Danger Is.

All terrestrial algal crusts were dominated by *Tolypothrix byssoidea*. Other species represented are listed in Table 5.

DISCUSSION

All these terrestrial and swamp algal communities are dominated by blue-green algae, and only in the *Typha - Eleocharis* swamp on Eagle Is. are eukaryotic algae represented by more than a few scattered cells. Three out of the six different types of algal community described from these three islands are dominated by *Tolypothrix byssoidea*, though the structure and composition of all three examples are each rather different. The extent to which this alga becomes calcified varies markedly, with the most highly calcified material occurring in the *Typha - Eleocharis* swamp. During the more detailed studies of the authors on Aldabra (Donaldson & Whitton, 1976; A. D. and B. A. W., unpublished data), no sample of *Tolypothrix byssoidea* has ever been found which approaches this swamp community in extent of calcification.

REFERENCES

Donaldson, A. and Whitton, B. A. 1976. Algal flora of freshwater pools on Aldabra Atoll. *Atoll Research Bulletin*, this issue.

Ginsburg, R. N. 1967. Stromatolites. *Science, N. Y.* 157: 339-440.

Golubić, S. 1973. The relationship between blue-green algae and carbonate deposits. In: Carr, N. G. & Whitton, B. A. (Eds) *The biology of Blue-green Algae*. 676 pp., pp. 434-472. Blackwell Scientific Publications, Oxford.

Stoddart, D. R. 1971. Rainfall on Indian Ocean Ocean coral islands. *Atoll Research Bulletin* 147: 1-21.

Whitton, B. A. and Donaldson, A. 1976. Terrestrial and freshwater algae of three Western Indian Ocean islands. *Atoll Research Bulletin*, this issue.

Table 1. Vertical zonation of thick barachois mat community, Egmont Is. Relative frequency of photosynthetic organisms in a particular zone of the profile is given on a (subjective logarithmic) scale of 1-5.

	depth colour	mm 0 - 0.05 olive-brown	0.05 - 1.5 olive	1.5 - 6 dark blue-green	6 - 9 pink	9 - 10
010532	*Aphanocapsa montana*	1	3			
010632	*Aphanothece* sp. > 2 $\leq$ 4 µm		2			
010902	*Calothrix braunii*					2
010911	*C. parietina*	2				
011538	*Chroococcus minutus*			2		
011534	*C. turgidus*			4		
014205	*Lyngbya digueti*	.		4		
015202	*Nostoc commune*	4 (± dead)				
015802	*Plectonema boryanum*			1	2	
016631	*Schizothrix* sp. $\leq$ 1 µm	4	5	3	3	
016931	*Spirulina subtilissima*				5	5
	purple photosynthetic bacteria (various species)					

Table 2. Consolidated list of algal species from barachois mat community, Egmont Is.

010531	*Aphanocapsa fusco-lutea* Hansg. > 1 ≤ 2 µm
010532	*A. montana* Cramer > 2 ≤ 4 µm
010632	*Aphanothece* sp. > 2 ≤ 4 µm
010902	*Calothrix braunii* Born. et Flah.
010911	*C. parietina* Thuret
011538	*Chroococcus minutus* (Kütz.) Näg. > 4 ≤ 6 µm, non-lamellate sheath
011534	*C. turgidus* (Kütz.) Näg. > 8 ≤ 16 µm, lamellate sheath
011540	*C. turicensis* (Näg.) Hansg. > 8 ≤ 16 m, non-lamellate sheath
012201	*Entophysalis granulosa* Kütz.
013602	*Hyella fontana* Hüber et Jadin
014205	*Lyngbya digueti* Gom.
015202	*Nostoc commune* Vaucher
015702	*Phormidium angustissimum* W. et G.S. West
015704	*P. foveolarum* Gom.
015802	*Plectonema boryanum* Gom.
015931	*Pleurocapsa minor* Hansg. ≤ 4 µm
015932	*Pleurocapsa* sp. > 4 ≤ 6 µm
016631	*Schizothix* sp. ≤ 1 µm
016931	*Spirulina subtillissima* ≤ 1 µm

Table 3. Species composition of four different algal communities, Eagle Is. The details given are generalizations based on a range of samples, and for composites where vertical zonation is apparent. Organisms seen only after cultures are indicated by +, rather than a frequency score.

		A	B	C	D
010531	*Aphanocapsa fusco-lutea* > 1 ≤ 2 μm			2	
010902	*Calothrix braunii*				+
010950	*Calothrix* sp.			+	
011534	*Chroococcus turgidus* > 8 ≤ 16 μm, lamellate sheath				1
011541	*C. spelaeus* > 16 ≤ 32 μm non-lamellate sheaths			2	
012640	*Gloeocapsa dermachroa* > 2 ≤ 4 μm sheaths yellow-brown		2		
012645	*Gloeocapsa* sp. > 2 ≤ 4 μm, sheath violet		1		
012732	*Gloeothece palea* > 2 ≤ 4 μm			1	5
012733	*G. rupestris* > 4 ≤ 6 μm			3	
013107	*Hapalosiphon welwitschii*			+	+
014202	*Lyngbya allorgei*	1			1
014211	*L. martensiana*	2	3		
014252	*Lyngbya* sp. > 1 ≤ 2 μm		2		
014801	*Microcoleus chthonoplastes*		1	2	3
015202	*Nostoc commune*	5		3	2
015218	*N. piscinale*			+	
015211	*N. punctiforme*			2	+
015704	*Phormidium foveolatum*			+	+
015511	*Oscillatoria claricentrosa*			2	
015802	*Plectonema boryanum*	+			
015932	*Pleurocapsa* sp. ≤ 4 μm				1
016602	*Schizothrix arenaria*		3	2	5
017601	*Tolypothrix byssoidea*	2	5	5	3
017606	*T. distorta*			+	+
062050	*Akanthochloris* sp.		1		
120250	*Closterium* sp.			1	
122150	*Spirogyra* sp.			2	
	palmelloid green alga (*c.* 13 μm diameter)			2	
160732	*Oedogonium* sp. > 8 ≤ 12 μm			1	
160801	*Pithophora oedogonia*			2	
239950	unknown moss(es)		2	3	

231-339 O - '77 - 14

Table 4. Vertical zonation of algal layer from mangrove swamp (community D in Table 3). Relative frequency of photosynthetic organisms in a particular zone of the profile is given on a (subjective logarithmic) scale of 1-5.

		0 - 0.5 pale brown	0.5 - 2.0 dark green	2.0 - 2.5 dark green	2.5 - 3.0 dark green	Fibrous layer brown
011534	*Chroococcus turgidus*	1	1			
012732	*Gloeothece palea*	5	5	4	4	3
014202	*Lyngbya allorgei*	2				
014801	*Microcoleus chthonoplastes*	2	2	2	4	
015202	*Nostoc commune*	2				
015704	*Phormidium foveolarum*	2				
015932	*Pleurocapsa* sp. ≤ 4 µm	2	1	1	1	
016602	*Schizothrix arenaria*	2	5	5	5	5
017602	*Tolypothrix byssoidea*	3	2			

Table 5. Species list for algal crusts from Danger Is.

010532	*Aphanocapsa montana* > 2 $\leq$ 4 μm
012640	*Gloeocapsa dermochroa* > 2 $\leq$ 4 μm, sheath yellow-brown
012641	*G. kutzingiana* > 4 $\leq$ 6 μm, sheath yellow-brown
014211	*Lyngbya martensiana*
014801	*Microcoleus chthonoplastes*
015202	*Nostoc commune*
015802	*Plectonema boryanum*
015817	*P. notatum*
015931	*Pleurocapsa* sp. $\leq$ 4 μm
016650	*Schizothrix* sp. (c. 4.5 μm wide)
017602	*Tolypothrix byssoidea*

ATOLL RESEARCH BULLETIN
NO. 218

THE HOLOCENE REEF SYSTEMS OF EASTERN MARTINIQUE, FRENCH WEST INDIES

by Walter H. Adey, Patricia J. Adey, Randolph Burke
and Leslie Kaufman

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

THE HOLOCENE REEF SYSTEMS OF EASTERN MARTINIQUE, FRENCH WEST INDIES

by Walter H. Adey,[1] Patricia J. Adey, Randolph Burke[2] and Leslie Kaufman[3]

ABSTRACT

The windward east coast of Martinique ranges from high, eroding Pleistocene volcanic cliffs in the north, to relatively low, early Tertiary, embayed shores partly capped by Pleistocene limestones, in the southeast. An extensive shallow carbonate shelf is developed off the central part of this coast. The types of Holocene reefs found on Martinique correspond to the pattern that is characteristic for Lesser Antillean islands: the volcanic northern coast is barren; massive algal ridges have developed on benches cut in the limestones and other early Tertiary rocks of the southeast coast; on the central east coast, where the shelf is well developed, an extensive and double bank barrier system has formed. Parts of the bank barrier reef system are reaching the mature stage typical of high energy coasts and have algal ridge caps built primarily by crustose corallines.

The bank barrier reefs of Martinique are unusual in that the corals have been replaced on the crests by a carbonate pavement covered with dense, diverse stands of fleshy algae, Sargassum spp. being especially common. The term "fleshy algal pavement" has been applied to this type of reef. Based on upstream-downstream measurements of dissolved oxygen, a winter productivity level of 33 gO_2/m^2/day indicates that these extensive reefs with their dense plant cover may be the most productive in the eastern Caribbean.

Though transitional and less extensive, reefs with fleshy algal pavements also occur on Grenada, St. Lucia, southeastern Basse Terre, and Nevis. All of these island shores are locally characterized by high sea water turbidities, presumably resulting from run-off, indicative of eutrophic conditions. However, where algal pavements are well developed,

1/ Smithsonian Institution, Washington, D.C. 20560
2/ University of South Florida, St. Petersburg, Florida 33701
3/ Johns Hopkins University, Baltimore, Maryland 21218

the reef surface also generally lacks extensive large scale porosity and large populations of Diadema antillarum. Large parrot fish of the genus Scarus are also very poorly represented, although this may result from a general lack of filamentous algal turfs normally characterizing their diet.

Based on C^{14} dating of cores, we have concluded that about 600 years B.P., the Martinique inner bank barriers shifted from Acropora palmata to fleshy algal domination. We postulate that the surfaces of these reefs developed into pavements by the filling of the interstitial reef spaces by either gradual or catastrophic means. This eliminated the large scale porosity required by algal grazers such as Diadema (and perhaps some parrot fish) in this high energy area.

In the reefs of the Grenadines where the surrounding waters are quite clear, similar carbonate pavements occur in the high energy areas, but lack a fleshy algal cover. We conclude that flat, featureless carbonate surfaces in areas of strong wave or current energy are conducive to the development of stands of fleshy algae. Especially where nutrient levels are high, massive stands of fleshy algae can become dominant on the reefs.

INTRODUCTION

Recent studies of Caribbean coral reefs, especially those of Adey and Burke, 1976, Macintyre and Glynn, 1974, and Adey, 1975, have demonstrated the existence of extensive reef structures with considerable accumulations of Holocene carbonate. In addition, massive algal ridges have been found in numerous localities throughout the Lesser Antilles (see Adey and Burke, l.c.). While there are undoubtedly fewer species of reef organisms in the West Indies than in the Indo-Pacific, this is probably largely due to the great difference in geographical area and to the relative isolation of the Caribbean during the Neogene. There is no field evidence for climatic inhibition of the rate of Holocene or earlier carbonate reef build-up in the Caribbean, a conclusion that correlates with new evidence for long term stability of Caribbean sea temperatures (Climap, 1976).

Research on living Lesser Antillean reefs has not been extensive. Prior to the recent work out of West Indies Laboratory, St. Croix (see W.I.L. Special Publications, beginning 1972), and the reconnaissance study of Lewis (1975) in the Grenadines, most studies had been done in areas of very limited Holocene reef development. Areas such as the east coast of Martinique had been considered devoid of reefs, in part due to the fact that the structures found in the area did not correspond to the popular conception of what a reef should be. The waters around Martinique tend to be turbid, with visibilities ranging from three to twelve meters, depending upon wave activity. Coral growth on the reefs is restricted, and has commonly been replaced on the crest by carbonate pavement covered with a heavy, diverse growth of fleshy algae, which we refer to as "fleshy algal pavement". Fish biomass is reduced as compared

to that found on the rich Caribbean Acropora palmata reefs. In spite of their unusual morphology, it would appear that Martinique's Holocene carbonate reef systems are among the most massive and extensive in the eastern Caribbean and biologically they may be among the most productive in the West Indies.

In the island arc extending from the Virgin Islands to Grenada, approximately eight hundred kilometers of windward coast is available for potential reef development (not including Barbados). As part of the present study, a reconnaissance survey of this coast has been made by boat and plane (Adey and Burke, 1976). As a result of these observations, the windward island shores of the Lesser Antillean island arc are found to fall into four categories: (1) barren, terrigenous (volcanic) sediments, 30% of total shoreline; (2) barren, non-volcanic, 14%; (3) bank barrier reefs on carbonate shelves at depths of 12-25 m, 38%; (4) reefs on shallow ($<$10 m) pre-Holocene benches, 18%. Approximately 52% of the bank barrier reef shores are dominated by fleshy algal pavement reefs such as found on Martinique, 36% by Acropora palmata reefs, and 12% by an A. palmata-algal ridge transition type characterized by crustose corallines and Millepora. Algal ridges in all stages of development occur in some areas as scattered caps on the bank barriers. Shallow benches, which occur primarily on the shores of limestone islands, are dominated by high algal ridges in exposed areas, and in more protected areas by A. palmata and coralline-Millepora reefs. In category (2) listed above are found some limestone island shores which are steeply cliffed, unbenched and without shallow reefs (5% of total), as well as some shores where the carbonate shelves are deep ($>$30 m) and also lack well developed reefs (9% of total).

Adey and Burke (1976) discuss the distribution of these reef types throughout the Lesser Antilles. These same authors (in ms.) present a model for control of Holocene reef development by the height of pre-Holocene shelves or benches, wave energy and water turbidity. The young northeastern coast of Martinique is characterized by steep cliffs cut in volcanic sediments, a narrow steeply slooping shelf and very minimal reef development. The older eastern and southeastern coasts, on the other hand, have a well developed shelf and are rich in Holocene reefs. Martinique is located in a peak of trade wind energy and constancy in the eastern Caribbean, and an index of wind strength and constancy shows a reduction to the north as well as the south (Adey and Burke, in ms.). East to southeastern Martinique is characterized primarily by bank barrier reefs with well developed fleshy algal stands on their crests. The southernmost part of the coast is dominated by a bench algal ridge system. These areas and their reef biotas are described below.

All of the authors listed took part in both the field work and the preparation of this paper. However the various sections were largely the responsibility of the following individuals: geological structure and history - Adey and Burke; corals - Burke; algae and productivity - Adey and Adey; fish - Kaufman.

DESCRIPTION OF THE REEFS

The following description includes the reefs from Presqu'ile de la Caravelle to Baie des Anglais (Fig. 1). It is based on three aerial reconnaissance flights, extensive examination, including coring and diving, at four sites (Vauclin Point reef, Cayes de Pinsonelle algal ridge, Islet de Ramville reef and Islet Lezard algal ridge) and numerous short visits to other points.

The reef between Passe du Vauclin and Cap Ferré has not been explored by diving. Aerial reconnaissance indicates that it is dominated by a fleshy algal pavement and with coralline-*Millepora* mounds on the crest in the north and a high algal ridge in the south, northeast of Point Macré. Thus, it is intermediate in character between the inner and outer systems that will be described below. Aerial reconnaissance also indicates that fleshy algal dominated reefs, with scattered coralline-*Millepora* mounds, exist near shore to the north of Caravelle, as far as Pte. Lahoussaye. This is apparently equivalent to the inner system to the south. Further to seaward, extending northwestward of Caravelle, a deeper ridge-like structure also occurs. This could be either a developing Holocene bank structure or a Pleistocene equivalent of the shelf edge features. We have not examined either of these areas in the water.

The major Holocene reefs of Martinique lie on the east coast between Presqu'ile de la Caravelle and the southeastern corner of the island. North of Passe du Vauclin they are arranged in a double (inner and outer) bank-barrier system. South of Cap Ferré, a single bench algal ridge system is predominant.

The double reef system, from Passe du Vauclin to Presqu'ile de la Caravelle, morphologically appears to be a set of bank-barriers developed during the middle Holocene atop the carbonate island shelf (Fig. 2). Bank barriers, which are common on many eastern Caribbean carbonate shelves, where depths are 15-25 m, typically consist of a coral or coralline framework cap (5-10 m thick) overlying a sand, rubble and head coral base. Adey and Burke (1976) suggest that these formed as "bars", largely during mid-Holocene, by coral head trapping of carbonate sand and rubble. Although the inner reef group in Martinique, which extends irregularly from Pte. du Vauclin to Baie du Galion, is rather atypical in form, paralleling the shore in a manner that is more characteristic of "bench" reefs, a series of holes bored in the Vauclin Point reef consistently penetrated the lower limit of the *Acropora palmata* facies at depths begween 4-5 meters (Fig. 3), below which carbonate sand with occasional coral rubble is the major component. In the deepest hole in Vauclin Point reef drilling character abruptly became very hard at 14 m. We were unable to obtain core at this point, but this suggests a basement contact. It may be that the particular orientation and embayed nature of the shoreline has allowed the formation of a bank, based upon a bench. Such circumstances would require the bench to be relatively deep, at least 14 meters. Profiles across the Martinique shelf suggest that it shoals landward to such a degree that, if such a bench is present, it does not rise far above the shelf proper. These inner reefs may be bank barriers formed against an abrupt change of slope at the contact of the carbonate shelf and the volcanic rocks forming the shore.

The outer system is also unusual for the Lesser Antilles in that the apparent basement is relatively deep (25-33 m). This may result from unusually massive sand and rubble buildup on an embayed and north-south oriented coastline. Another possibility is the presence of a Pleistocene reef structure lying under the outer system. Our deepest core at Pinsonelle (Fig. 5) extended to only 13 m, however repeated drillings through the bank barrier in St. Croix (Adey and Burke, in prep.) as well as the minimum bank thickness at Vauclin reef (Fig. 3) and the shelf profile (Fig. 2), suggest that such an old reef core is not likely. Although other double bank-barrier systems are known in the Lesser Antilles (e.g., World's End and Horseshoe Reefs in the Grenadines), the Martinique system is the most extensive of these.

Profiles across several other points on the inner reefs (Figs. 5-7) are generally similar to that of Vauclin reef. Although it is not obvious on figure 1, it can be seen on the standard marine chart (HO 1009) that Sans Souci (inner), Pte. de la Prairie and especially Ramville Island reefs are more exposed than Vauclin Point reef. As a result, these reefs tend to be shallower near the crest, and both Ramville and Pte. de la Prairie have numerous low algal mounds and spurs (incipient algal ridges). These features are particularly apparent from the air, especially during low tides, but can be very difficult to see from a boat unless the sea is calm.

The inner reef system apparently developed extensive _Acropora palmata_ caps over the bank-barrier foundation in the late Holocene. Large samples, extracted from the "clean" cores of several _A. palmata_ arms, from the top and bottom of this facies in Vauclin reef gave C^{14} dates of 560 and 1670 years B.P. respectively. Most of the _A. palmata_ excavated in a 3 m^2 hole dug to a depth of 2 m into the reef crest (Fig. 3) appeared to be in growth position. Today this coral only dominates a narrow and irregular band on the front faces of these reefs just below the zone of heavy algal growth.

Coring on the very high energy ramparts of Pinsonelle algal ridge (Fig. 4), indicates that crustose corallines have dominated the frameworks of the algal ridges on this system for at least two thousand years; a single C^{14} date from a narrow _A. palmata_ band at a depth of 4-5 m was 2110 years B.P. Although we cored only in an emergent area on the outer system, the similarity in position and appearance of these structures would indicate that the results obtained at Pinsonelle are valid generally. It would be especially desirable to obtain a coring through to the Pleistocene shelf in an area where no algal structures have reached surface level, such as at Cayes de San Souci (see Fig. 8). However, there is little reason to believe that the basement in such cases is any shallower than at Pinsonelle. At Passe du Brigot an algal ridge is developed on both sides of the channel, and a section across the north ridge (Fig. 9) is very similar to that at Pinsonelle both with regard to depth profile and animal and plant populations (Fig. 10).

A single hole was drilled in the southern Martinique "bench-ridge system" at Lezard Is. (Fig. 11). At eight and one half meters below the surface of the ridge, drilling resistance increased markedly, suggesting

a transition from predominantly crustose coralline material to rock basement. However, a drill rod broke at this point, and we were unable to retrieve the bit and obtain core from the base of the hole. Our interpretation of these structures as "bench type" is based primarily on their location near shore, very shallow lagoons, and association with several predominantly limestone islands upon which wave cut terraces could have been formed at a period of lower sea level (see Adey and Burke, 1976). A similar drilling pattern was encountered in the bench algal ridge at Chateaux Point, Guadeloupe, where limestone basement was obtained with great difficulty from 7 m down.

The present eastern Martinique reef complex is characterized by an overwhelming dominance of large standing crops of fleshy benthic algae in crest and upper fore-reef areas, especially of the genera Sargassum and Gracilaria. This characteristic is also shared by some of the reefs of southeastern Basse Terre, St. Lucia, Grenada, and Nevis (see Adey and Burke, l.c.). Otherwise, such extensive fleshy algal reefs do not generally occur on Lesser Antillean islands except locally on sheltered and low "old" algal ridges (Connor and Adey, 1976). (Note the apparent fleshy algal covered pavement on high energy eastern Curacao (Van den Hoek et al., 1975.) The reasons for this somewhat unique algal dominance is surely due in part to the limitation of grazing by fish (Scaridae and Acanthuridae) and echinoids (Diadema antillarum) by the high wave energy. However, similarly shaped reefs with about equivalent wave action (see Adey and Burke, in ms.) in the Grenadines lack a fleshy algal cover. Through the Lesser Antilles, there appears to be a correlation of algal pavements with high turbidity; all of this is discussed below.

CORALS

P. J. Roos, in his 1971 study of the stony corals of the Netherland Antilles referred to a private collection of twelve species from Martinique made by P. W. Hummelinck. Eleven of these species were found during the course of the present study, Solenastrea bourni being the only exception, which was perhaps overlooked due to its similarity to the more abundant Montastrea annularis. Twenty-two additional species, including four major carbonate-producing Hydrozoans, have been identified and are listed in table 1. Their distribution along several inner and outer bank barrier transects is shown in figures 5-10.

Coral diversity on the lower fore-reef zones of the inner system is rather high, but total populations do appear to be generally low relative to comparable reef surfaces in St. Croix, Antigua or the Grenadines. The number of scleractinian species observed is about fifty percent of that reported from the intensive investigations in Jamaica (Goreau and Wells, 1967). However, as Roos (l.c.) noted "...there is considerable variation in important (diagnostic) characteristics...and great variation in growth form (of many of the corals and therefore) the great number of species of Agaricia in Goreau and Wells (1967) has to be interpreted with care." We conclude that this caution must be applied to some other genera as well. Thus, no attempt has been made to differentiate beyond the generic level for numerous morphologies of

Agaricia spp., Mycetophyllia spp., and what are apparently Colpophyllia spp. The list of coral species presented here (Table 1) could probably be increased by thirty to forty percent if taxonomic distinctions were clearer.

Inside the inner reef system water circulation and turbulence are restricted, creating conditions suitable for well developed lagoonal communities. Many of the inner bays have extensive mangrove populations, and coral production is low. However, in the lagoon area immediately behind the inner reefs, extensive beds of Thalassia testudinum and Syringodium filiforme as well as a complementary benthic algal population (see below) are found. The primary corals found here are Manicina areolata, and four species of the family Poritidae, Porites astreoides, Porites divaricata, Porites furcata, and Porites porites, the latter three species being most common. Also, associated with these are the two species of the family Siderastreidae (Siderastrea radians and Siderastrea siderea), which inhabit all other zones of the reef as well. Occasional scattered colonies of Diploria clivosa, Diploria strigosa and Oculina valenciennesi (near shore) are also common. An extremely delicate form of the Hydrozoan Millepora alcicornis is abundant in the shallow seagrass zone adjacent to the immediate back reef. Apparently this species prefers these shoal areas, which are characterized by a considerable current but low turbulence. This is also a common location for the formation of circumrotary corals (free nodules) by both Siderastrean species.

Except for the reef crest, which is locally dominated by the Hydrozoans M. complanata, and M. squarrosa, the back and upper fore reefs are characterized by large standing crops of fleshy algae and generally only a few scattered corals.

The area of coral dominance on the inner reef system is restricted to the fore reef and extends from just beneath the zone of heavy algal growth at a depth of 3-4 meters, to the sand at 10-15 meters. Because of the turbid water and the resultant reduction of light penetration, the corals within this zone represent a community usually found within a much wider depth range, and many colonies have assumed the plate-like form usually associated with deep water, although these are generally of less fragile construction.

Below the algal zone, the abundance of the various species of the order Faviidae increases with depth and then decreases again near the base of the deep fore reef. The members of the family Faviinae, including Favia fragum, D. clivosa, D. strigosa, Diploria labyrinthiformis and Colpophyllia natans, are common over the entire reef, although the latter two species are more common on the fore reef. The family Montastreinae (represented by Montastrea annularis and Montastrea cavernosa) is generally more common near the break in the fore reef slope and on the deep fore reef. Although there are some marked species preferences in the upper and lower portions of the fore reef slope (Acropora palmata above and D. labyrinthiformis and Colpophyllia spp. below), the most striking change in coral populations is in their morphologies.

The general trend of coral morphology, changing with increasing depth from crusts to heads to foliose, is similar for most major corals at all locations carefully examined on Martinique. The trend, however, is especially marked in Diploria spp., Montastrea annularis and Porites astreoides. Primarily encrusting forms of Diploria clivosa and Diploria strigosa and hummocky mounds of P. astreoides are found in the areas dominated by fleshy algae near the outer part of the algal pavement. Further seaward, they assume a hemispherical shape and are locally associated with patches of Acropora palmata. On the steeper fore reef, most corals gradually adopt the foliose morphology. Foliose Diploria spp., M. annularis, P. astreoides and Colpophyllia spp. shingle wide areas of the reef face and associated pillars, from the break in the fore reef slope to the base of the deep fore reef, over a depth range of up to ten meters.

Additional components occurring near the base of the deep fore reef community include Scolymia lacera, Meandrina meandrites, Mycetophyllia spp., and Siderastrea siderea.

On the outer reef system (Figs. 4, 8-10), the scleractinian corals are concentrated along the deep fore reef and also occur locally in back reef (reef flat) areas behind the algal ridges. The deeper fore reef community seems to be rather homogenous from our observations of three different localities, Pinsonelle, Cayes du Vauclin and Cayes de San Souci. Where the slope steepens markedly, there is a sharp decrease in fleshy algae and a corresponding increase in the frequency of corals. The Hydrozoan Millepora squarrosa, and three Diploria spp., especially D. labyrinthiformis, occasional A. palmata, along with the secondary corals (e.g., Favia spp., Siderastrea spp., P. astreoides) dominate the transition across the slope break. A gradual increase in M. annularis, Colpophyllia spp., Montastrea cavernosa, and large S. siderea then occurs down the reef face. These coral communities also occur on the sides of the deep sand channels and patches that are scattered over the fleshy algal pavements.

The back reef areas behind the algal ridges of the outer system are much more complex in that large patches of less energy tolerant species (A. palmata, P. porites) are locally very abundant. The back reef slope (sand cliff) is mostly occupied by seagrass communities, though well developed faviinid reefs of M. annularis, Diploria spp. with abundant alcyonarians occur locally. Occasional A. palmata colonies also occur in this area.

There are a few major Caribbean coral species that are relatively rare in the Martinique reef system. Agaricia agaricites, which characteristically shingles vast areas on deep reefs in Jamaica and shallow areas in Belize, is rather uncommon here. Similarly, Acropora cervicornis, which is moderately common on fore reefs of the Grenadines, Guadeloupe, Antigua, and the Virgin Islands and is a mid-reef framework builder in the central and western Caribbean, was found living only at the base of a patch reef in Havre du Robert.

BENTHIC ALGAE

As described above, on Martinique the crustose corallines are the main builders of the algal ridge caps on the outer reef system, the near-shore bench ridges in the south, and the incipient ridges forming on the crest and upper fore reef along the inner system. They also form a thin crust over much of the surface of the algal pavements of both the outer and inner reef systems. The taxonomy and ecology of crustose corallines in the Caribbean is presently under study (WHA), and, as many of the species are as yet undescribed, only a brief treatment of the dominant elements is given here.

In the deeper zones of the reefs throughout the Caribbean, the crustose corallines are poorly represented, although the genera Paragoniolithon (n. gen.), Neogoniolithon, Hydrolithon and Tenarea do occur. However, in the shallower zones that are dominated by Acropora palmata and Millepora complanata, the corallines typically encrust large portions of the usually abundant dead coral substrate. Porolithon pachydermum, Neogoniolithon megacarpum (n. sp.) and Lithophyllum congestum are dominant in well lighted areas, and Neogoniolithon accretum, Hydrolithon borgesenii and sometimes Lithothamnium ruptile and Paragoniolithon solubile are important in shaded situations (see Adey and Vassar, 1975; Van den Hoek et al., 1975). On rubble fragments scattered around the corals and patches, Hydrolithon borgesenii and sometimes Neogoniolithon mamillare are usually the dominant encrusters. The coralline populations on the inner reef system of Martinique is generally typical in the narrow A. palmata band and deeper fore-reef zones.

Although some Caribbean algal ridges are characterized by frameworks of the anastomosing branching type of L. congestum (Steneck and Adey, 1976), this has not been found to be the situation on Martinique and Guadeloupe, perhaps due to physical damage to this plant caused by higher energy levels. Although L. congestum occurs in this area, the ridges appear to be built largely by Porolithon pachydermum with a considerable admixture of Millepora.

On the fleshy algal pavements (which occupy the zones ordinarily dominated by A. palmata in other areas) the crustose coralline population is quite unusual beneath the heavy plant cover. Here Neogoniolithon n. sp., Mesophyllum n. sp., Lithophyllum n. sp. and Archeolithothamnium n. sp., all shade plants, are abundant. Most of the plants usually associated with A. palmata, with the addition of Archeolithothamnium dimotum, also occur on these pavements, but are much less abundant than those listed above. All of the species, except Archeolithothamnium n. sp., have been found in scattered localities elsewhere in the Caribbean, where they occur locally under fleshy algal patches. The Archeolithothamnium n. sp., a large, coarsely branched plant, is presently known only from Martinique.

The fleshy algae dominating the crest of Martinique reefs are both diverse and abundant. The Vauclin Point pavement, with over 100 species of macro-algae and an average standing crop of about 4 kg/m^2 (wet), is richer than any previously described equivalent tropical area (see Connor and Adey, 1976). (Van den Hoek et al., 1975, reported 142 algal species

from a transect across the shore in south west Curacao. However, the transect included both shore and deeper zones. The maximum number in that study for a community-zone was 55. An equivalent number for the back algal pavement in this study would be over 90.) A series of 0.25 m^2 areas were collected in transects across Vauclin Point reef and Pinsonelle algal ridge. Standing crop measurements of the dominant species found are shown in figures 12 and 13. Numbers of quadrats, species encountered, frequency and standing crop by species are given in table 2.

On the Vauclin Point pavement, the maximum standing crops of fleshy algae are found on the upper fore reef (seaward of the surf zone) and on the back reef areas. There is a marked decrease in the standing crop in the surf zone, mostly due to a reduction of Sargassum platycarpum. On the algal ridge at Pinsonelle, the reduction of standing crop in the very high energy zone (which is also largely intertidal) is much more marked. Here, except for a small amount of Sargassum vulgare, virtually all of the species occurring on the fore and back ridge pavements are absent, and several Laurencia species dominate.

The Sargassum species are the major elements on the Martiniquan reef and ridge crests, although several Gracilaria, Dictyopteris, Dictyota and Laurencia species also occur in abundance. Floating Sargassum is frequent on these shores during periods of rough seas, suggesting that it is torn off by wave action (the relationship between wave action and algal standing crops over several years was described by Doty (1971a) for a Hawaiian algal pavement). On the other hand, heavy wave activity seems often to be associated with the presence of dense algal growth, perhaps serving to inhibit the predation of Diadema antillarum and parrot and surgeonfishes (mainly Sparisoma rubripinne and Acanthurus bahianus). Thus, Sargassum appears to reach high densities within a relatively narrow range of wave energy. Large algal stands do occur intertidally (on algal ridges) in relatively quiet St. Croix, but in Martinique, they extend down to 3-4 m on the medium-high energy inner reefs, and reach 10-15 m on the very high energy outer system.

With adequate protection, D. antillarum can probably survive long periods of intense wave action without moving from shelter. Within the area of dense algal growth behind the crest at Vauclin Point reef are several bare depressions occupied by large groups of Diadema. These typically cover an area of about 3 x 5 meters and are approximately 50 cm deep, sharply delineated at the upper rim by the surrounding algal forest. Apparently the urchins are kept within these patches by the force of current and swell as well as the whipping action of the long Sargassum fronds. During periods of especially intense wave activity these patchy Diadema seem to be restricted even more narrowly and pioneer algal growth begins to encroach upon the bare carbonate areas. As conditions return to normal, however, this new growth quickly disappears. Areas adjacent to the barren Diadema depressions, when cleared of their heavy algal growth are usually kept clear by Diadema grazing when wave energy stays at moderate levels. However, under rough conditions these areas are slowly re-covered with fleshy algae. It would appear that if wave action were to diminish greatly for a considerable length of time, the Diadema already present on the reef could decimate the algal stand. Therefore consistency of wave

action would seem to be as critical as intensity. This might provide one explanation for the extent of the algal pavements that are present on Martinique, located as it is in the zone of maximum trade wind constancy.

Our studies have indicated that three factors are related to the presence of sublittoral fleshy algal pavements: strong wave energy, smooth carbonate pavement and turbid waters. In addition to the inhibition of grazing activities that has been discussed above, it is also likely that wave energy plays an important role in the formation of smooth carbonate pavements by reduction of the coral population through breakage and the filling of the reef matrix with transported sediment and debris. Once such a smooth pavement is formed, grazing is further reduced because holes and niches used for protection by reef organisms are drastically reduced in number. However the combination of high wave energy and smooth carbonate pavement is usually not enough in itself to stimulate the formation of heavy fleshy algal growth, as is evidenced in many reefs in the Grenadines where the water is quite clear. It would seem that turbid water, probably rich in nutrients, is also required for the general heavy growth of fleshy algae, as has been observed by Adey and Burke (1976).

As has been discussed above, the crests of Martinique reefs were not always covered by fleshy algal pavements, but were dominated in the past by Acropora palmata, although it is probable that the water turbidity and energy conditions were not significantly different during that period than they are today. It seems likely that the changeover occurred when the A. palmata reef grew to near sea level and gradually was transformed by wave energy into a carbonate pavement upon which fleshy algae could flourish in the turbid water.

PRODUCTIVITY

Coral reefs are biologically among the most productive systems known. Oxygen exchange rates (based on changes in oxygen concentrations in water flowing over reefs and transformed to organic carbon), have been used to obtain gross figures of about 5 to 25g C/m^2/day. In a typical Caribbean A. palmata reef environment, living corals and coralline algae cover a relatively small proportion of the total reef surface. Usually, much of the total area at any one time consists of dead coral substrate with a short, dense turf of small filamentous algae, blue-greens often being abundant. An algal ridge or pavement with a large standing crop of fleshy algae might be expected to be more productive than a typical coral reef; Connor and Adey (1976) suggested this in the study of an algal ridge lobe on St. Croix, where values of 24 to 45 C/m^2/day were obtained.

Preliminary oxygen exchange studies were undertaken on both Vauclin Point reef and Pinsonelle algal ridge, using the Winkler method for measuring dissolved oxygen. At Vauclin Point reef, the breaker zone begins approximately one third of the way back from the seaward margin of the algal pavement. For each of the 15 sets of oxygen data taken, five samples were collected: seaward of the reef; beginning of the algal zone;

beginning of the breaker zone; end of the breaker zone; at the landward limit of the pavement. By plotting these data as a function of position and measuring water flow (float bottles) over the reef, it was possible to determine gain or loss of oxygen in the breaker zone and the net exchange of oxygen between reef surface and the water in terms of $g/m^2/hr$. Dissolved oxygen values of 6 to 7.2 mg/l were found across the Vauclin Point reef and mid-winter results for both clear and partly cloudy (overcast) days are shown in figure 14. From these data, a gross productivity for the clear day of approximately 33g O_2/m^2/day or 10g C/m^2/day was determined. This is well below that obtained by Connor and Adey (l.c.) for the St. Croix algal ridge in April. However, the marked difference between the cloudy and the bright days suggests that, even at this latitude, daily and seasonal differences may be considerable. Summer productivity probably is considerably higher.

Only a single series of oxygen samples were taken across the Pinsonelle algal ridge, on the second of January. The oxygen concentrations rose from 6.8mg/l in front, to nearly 8.1mg/l immediately behind the ridge pavement system. About two-thirds of this rise occurred on the rather short back ridge algal pavement, indicating that this very shallow area is considerably more productive than the deeper Vauclin Point pavements. This further suggests strong limitation of productivity with decreasing light in sublittoral reef systems. Adey at al. (studies in progress) found gross oxygen production in Rod Bay, St. Croix during November to be 17g O_2/m^2/day for a 1 m deep mixed coral and algae backreef and 13g O_2/m^2/day on a typical _Acropora palmata_-algal turf fore-reef with an average depth of about 4 m. (Very similar levels of 17 and 10g O_2/m^2/day, respectively, were also predicted using species productivity values of Doty (1971b) and the standing crops of algal turfs typical of the reef.) Thus, for approximately the same depth (1m), productivity on the Martinique algal pavement was twice that of the back reef on St. Croix. This agrees with the theoretical consideration that while filamentous algae generally show 10-20 times greater productivity per unit weight than the more massive algae (Doty, l.c.), the standing crops of massive fleshy algae on these algal pavements are 20-30 times greater than that of filamentous algal turfs in a "coral" reef.

These data suggest that with very extensive algal pavements at depths of 1-2 m, the reef systems of Martinique are probably the most productive in the eastern Caribbean.

FISHES

The fish assemblages of the algal-dominated Martinique inner reef system differ markedly from those of typical _A. palmata_ and mixed _A. palmata_-coralline-_Millepora_ reefs of the eastern Caribbean. The fishes associated with coral and bare carbonate areas are similar to those of the mixed reefs, although certain conspicuous species are rare or absent. The fleshy algal pavements are heavily populated with typical grass bed populations usually alien to the mixed and _A. palmata_ reefs. This contrast in fish assemblages may be explained by the general

disruption of small scale habitats as the formerly Acropora palmata dominated reefs of Martinique acquired their fleshy algal pavement caps.

During February-April 1975, about one hundred hours between 0900 and 1900 were spent observing fishes at five general locations on Martiniquan reefs: Ramville Island, Sans-Souci channel and Pte. du Vauclin on the inner bank barrier system; at Lezard algal ridge on the southern bench system; and on the more protected parts of Loup Garou on the outer bank barrier system. Assemblages were described by snorkeling or SCUBA diving within a broadly defined habitat (e.g., fleshy algal pavement) and recording the relative abundances of the fishes seen. Data were recorded with time from the beginning of each observation period, allowing the construction of sampling effort (time)/species number curves. From these curves it was determined that even in the most heterogenous environments, where frequent crossing of broad habitat boundaries complicated data recording, fifty to sixty minutes was usually sufficient to record over ninety percent of the visible species. The required time was somewhat longer in regions of high wave energy and turbidity. The major patterns discussed here include only the most abundant species. These were often observed within the first thirty seconds, without significant change in relative abundance estimate over several hours of observation. The relative merits and drawbacks of visual population estimates of reef fishes have been discussed by Bardach (1959) and reviewed by McVey (1972) and Gunderman and Popper (1975).

Table 3 lists all species encountered during the Martinique study, grouped in order of greatest relative abundance. Table 4 compares the relative abundance of several characteristic fishes on fourteen eastern Caribbean reefs, including Martinique. The reefs have been categorized on the basis of dominant surface features; Union Island, Goyave and Nevis reefs include patches of two categories.

As seen from Table 4, compared to mixed A. palmata-coralline-Millepora reefs, "pure stands" of A. palmata had fewer parrotfishes and were missing many other species. Randall (1967) noticed smaller populations of fishes on "Luxuriant reefs of Acropora palmata..." and attributed this pattern to "...limited food for fishes which feed on attached marine life or organisms therein," in spite of the excellent shelter provided by the continuous coral cover. Our experience on Rod Bay Reef, St. Croix, where living A. palmata occupied less than 30% of the surface and algal turfs are responsible for 80% of the productivity, further suggests that grazing fish may be food limited on extensive "pure stands" of A. palmata.

The Martiniquan reefs differ even more dramatically from those with both patchy A. palmata and coralline-Millepora pavement. Many species are missing from Martinique and even Sparisoma viride and Scarus vetula have a very restricted distribution. However the reefs support a much greater proportion of grass bed fishes such as the bucktooth parrotfish, mutton hamlet, and blackear and dwarf wrasses (occurrence in grass beds cited from Randall, 1968; Bohlke and Chaplin, 1968). This peculiarity of the fish populations is almost certainly not biogeographical, since all of the absent species are found on reefs both to the north and south, and

no special biogeographical boundaries fall through this area. Furthermore, at the reef at Goyave, Gaudeloupe (which is apparently in the process of developing from a typical Acropora palmata reef into one with a fleshy algal cover) there are adjacent patches of fleshy algal pavement and A. palmata surrounded by coralline-Millepora pavement. The assemblage on the fleshy algal pavement is similar to that of Martinique, while the assemblage on portions dominated by A. palmata is typical of this type of reef.

From Table 4 it can be seen that the Martiniquan fish assemblages resemble those of other reefs with extensive fleshy algal pavements much more than those with extensive A. palmata or mixed patches of A. palmata and coralline-Millepora pavement, even where they occur on the same island. This suggests that the fish assemblages on fleshy algal pavement reefs are due to either structural or food resource characteristics of these reefs which differ from those of A. palmata or mixed reefs.

The large Scarus spp. and Sparisoma viride are characteristically grazers and scrapers of carbonate surfaces rather than browsers on the larger fleshy algae. Their main food in a typical A. palmata reef is probably the abundant algal turfs growing on dead coral (Randall, 1967), often the most significant primary producers in this environment (Adey, studies in progress). It is possible that pavement reefs with dense fleshy algal stands do not have sufficient food resources of the proper type to maintain these big turf grazers.

Most parrot fishes form herds in open water, a behavior which is probably facilitated by bright color patterns (Hamilton, in press). When encountering the snorkeler (and presumably any other potential danger) large Scarus spp. and S. viride disappear beneath ledges or among interlocking arms of A. palmata. Since reefs dominated by fleshy algal pavements usually lack this shelter as well as grazeable algal turfs, these fishes would be forced to adopt rather different habits to survive there as adults. Apparently this has not occurred for any of the larger parrotfishes excepting the yellowtail, Sparisoma rubripinne. When encountered away from shelter, this species assumes a mottled, cryptic color pattern and nestles down against the algal cover. On the pavements at Martinique, Nevis and Guadeloupe it was usually observed browsing on fleshy algae rather than grazing on the small amount of turf-covered coralline pavement that was available. Ten S. rubripinne were shot for stomach analyses. Stomach contents were difficult to identify to species, however most were filled with fleshy fragments. Thus S. rubripinne seems much better suited to life on the fleshy algal pavements than S. viride or any of the large Scarus spp.

Sparisoma radians is also capable of cryptic coloration and behavior on fleshy algal pavement, as well as feeding on the algae growing there. Randall (1967) found it feeding primarily on Thalassia in grass beds. The mutton hamlet and dwarf and blackear wrasses are cryptic carnivores that are capable of matching any mottled green or brownish substrate. Since they are abundant both in grass beds and on fleshy algal pavement, they apparently do not prey exclusively on organisms peculiar to one or the other of these habitats.

Many fishes which can reach great abundance on all reef types are of extremely localized distribution on fleshy algal pavements. For example, it has been demonstrated that juvenile Eupomacentrus planifrons (threespot damselfish) inhabit live, branching coral ("bushes") which the fish kills as it matures (studies in progress - Kaufman). Adults prefer dead corals of similar morphology, on which they "farm" small fleshy algae by chasing herbivores from a territory. This study was performed at Jamaica and St. Croix, but similar patterns of micro-distribution for this and other species were observed throughout the eastern Caribbean and the Florida Keys. In Martinique, juvenile E. planifrons were fairly abundant on back-reef Porites porites shoals and fissured rocks, but nowhere else. Adults were restricted almost entirely to small patches of A. palmata on the fore-reef, where they defended territories on dead coral.

Observations on the local distributions of many other species tend to support the hypothesis that differences in fish assemblages between reefs dominated by fleshy algal pavements and those dominated by living A. palmata and/or algal turf-covered coralline-Millepora pavements are primarily due to differences in either or both habitat structure and food resource availability. The reefs of Martinique assumed their present character approximately 600 years B.P., before which the reefs were dominantly A. palmata. Presumably, the fish assemblage at that time was as different from that found today as are those of existing A. palmata reefs. In assessing the historical effects of fishing on local populations, one should note that major changes in the distribution and abundance of Caribbean reef fishes probably have occurred as the reefs themselves have matured. In many respects, these changes may be independent of man's activities, and are probably still in progress today.

ACKNOWLEDGMENTS

The authors are grateful to the Martinique Prefectural Government, which freely gave the permission, visas and customs clearances required to pursue this study. The American Consulate in Fort de France, and especially Vice Consul Thomas L. Randall, Jr. helped us in numerous ways. Special thanks are due to Raymond and Margarite Asselin of Vauclin, who allowed us to work out of their cottage on Petite Grenade Island. Claude and Jacqueline DeLeuze of Vauclin provided very welcome assistance in the form of equipment loan and help in locating necessary facilities. In addition to the authors, Judith Connor and Michael Vassar, assistants to the Coralline Program, also participated in many aspects of the investigation. John Ogden and Lee Gerhard of West Indies Laboratory, St. Croix and Patrick Colin of the University of Puerto Rico read the manuscript and offered valuable suggestions for its improvement. The project was supported by the Smithsonian Research Awards Program and Smithsonian Secretary's Fluid Research Fund.

REFERENCES

Adey, W. 1975. The algal ridges and coral reefs of St. Croix: their structure and Holocene development. Atoll Research Bull. 187:1-67.

Adey, W. and J. M. Vassar. 1975. Succession and accretion rates in Caribbean crustose corallines. Phycologia 14:55-69.

Adey, W. and R. Burke. 1976. Holocene bioherms (algal ridges and bank barrier reefs) of the eastern Caribbean. Geol. Soc. Am. Bull.

Adey, W. and R. Burke. In Ms. Holocene bioherms of the Lesser Antilles: geological control of development. A.A.P.G. Mem.7th Caribb. Geol. Congr.

Bardach, J. 1959. The summer standing crop of fish on a shallow Bermuda reef. Limnology Oceanogr. 4:77-85.

Bohlke, J. E. and C. C. G. Chaplin. 1968. Fishes of the Bahamas and Adjacent Tropical Waters. Acad. Sci. Philadelphia. 771 pp.

Climap Project Members. 1976. The surface of the ice-age earth. Science 191 :1131-1137.

Connor, J. and W. Adey. 1976. The benthic algal composition, standing crop and productivity of a Caribbean algal ridge. Atoll Research Bull.

Doty, M. S. 1971a. Antecedent event influence on benthic marine algal standing crops in Hawaii. Mar. Biol. Ecology 6:161-166.

Doty, M. S. 1971b. The productivity of benthic frondose algae at Waikiki Beach, 1967-1968. Hawaii Bot. Sci. Paper 22:1-119.

Goreau, L. and J. W. Wells. 1967. The shallow water scleractinia of Jamaica: revised list of species and their vertical distribution range. Bull. Mar-Sci. 17:442-453.

Gunderman, N. D. and D. Popper. 1975. Some aspects of recolonization of coral rocks in Eilat, Gulf of Aquaba by fish populations after poisoning. Mar. Biol. 30:109-117.

Hamilton, F. In press. Functional coloration of coral reef fishes. Cited in Coral reef ecology, C. L. Smith (ed.).

Lewis, J. 1975. A preliminary description of the coral reefs of the Tobago Cays, Grenadines, West Indies. Atoll Res. Bull. 178:1-9.

Macintyre, I. 1972. Submerged reefs of the eastern Caribbean. Am. Assoc. Petr. Geol. Bull. 56:720-736.

Macintyre, I. and P. Glynn. 1974. Internal structure and developmental stages of a modern Caribbean fringe reef, Galeta Point, Panama. VIIth Caribbean Geol. Conference. Abstracts p. 40.

McVey, J. P. 1972. Ecology of the Pokai Bay artificial reef, Oahu. Univ. Hawaii Contr. 114-16000133461. 29 pp.

Randall, J. E. 1967. Food habits of reef fishes of the West Indies. Cited in: Proceedings of the International Conference on Tropical Oceanography. 847 pp. University of Miami, Miami, Fla.

Randall, J. E. 1968. Caribbean reef fishes. T.F.H. Publication, Inc. Jersey City. 318 pp.

Roos, P. J. 1971. The stony corals of the Netherlands Antilles. p. 1-108. in Studies on the Fauna of Curacao and other Caribbean islands. No. 371. P. W. Hummelinck, ed., The Hague.

Steneck, R. and W. Adey. 1976. The role of environment in control of morphology in Lithophyllum congestum, a Caribbean algal ridge builder. Botanica Marina.

Van den Hoek, C., A. Cortel-Breeman and J. Wanders. 1975. Algal zonation in the fringing coral reef of Curacao, Netherlands Antilles, in relation to zonation of corals and gorgonians. Aquatic Botany 1:269-308.

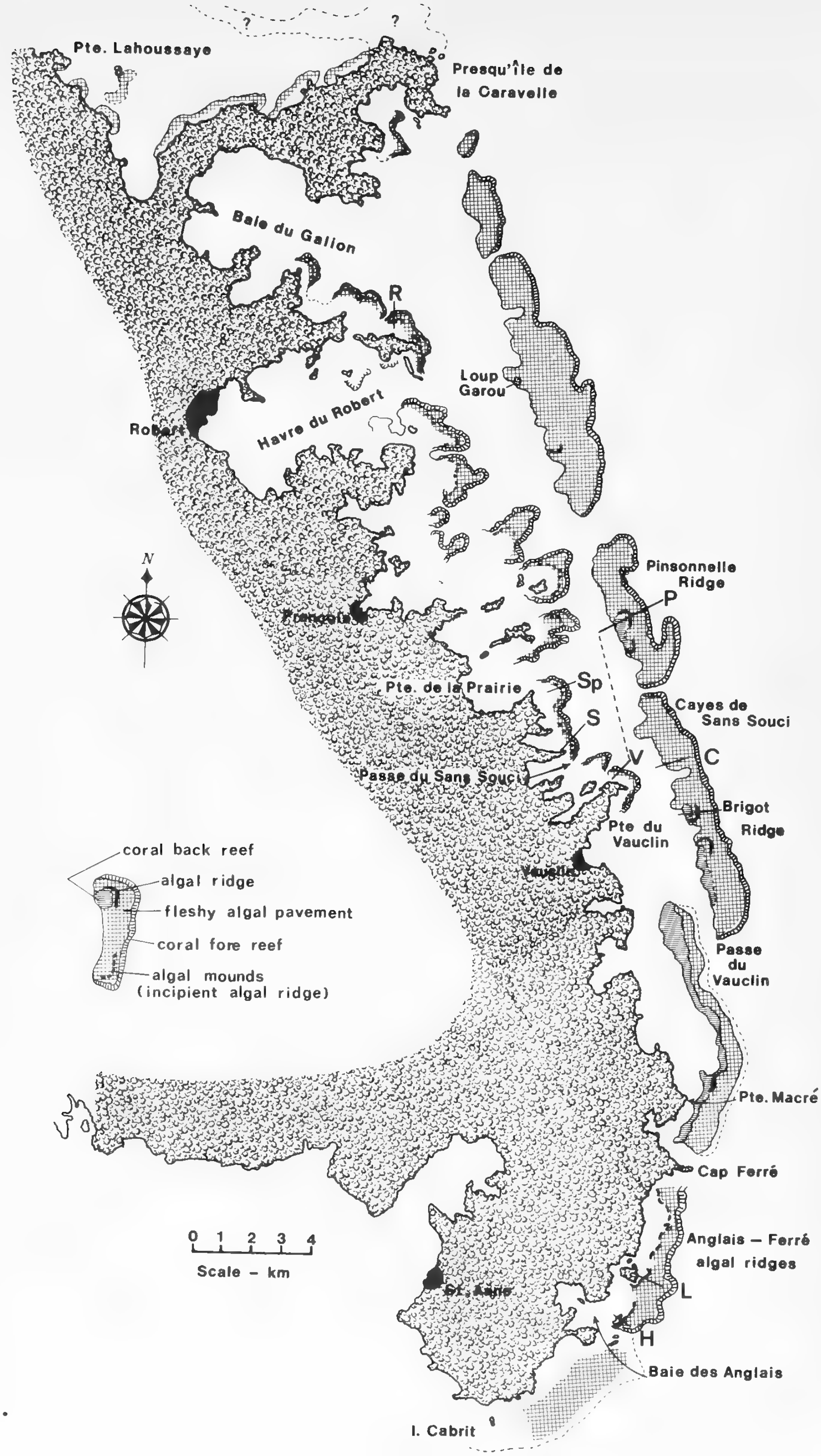


Fig. 1.

Holocene bioherms on eastern Martinique. Transects: H - Hardy Is., L - Lezard Is. (Fig. 11); Brigot Ridge - Cayes du Vauclin (Fig. 9); C - Cayes de San Souci (Fig. 8); P - Pinsonelle algal ridge (Figs. 4, 10); V - Vauclin Point (Fig. 3); S - San Souci channel (Fig. 7); Sp - Pointe de la Prairie (Fig. 7); R - Ramville Is. reef (Fig. 5)

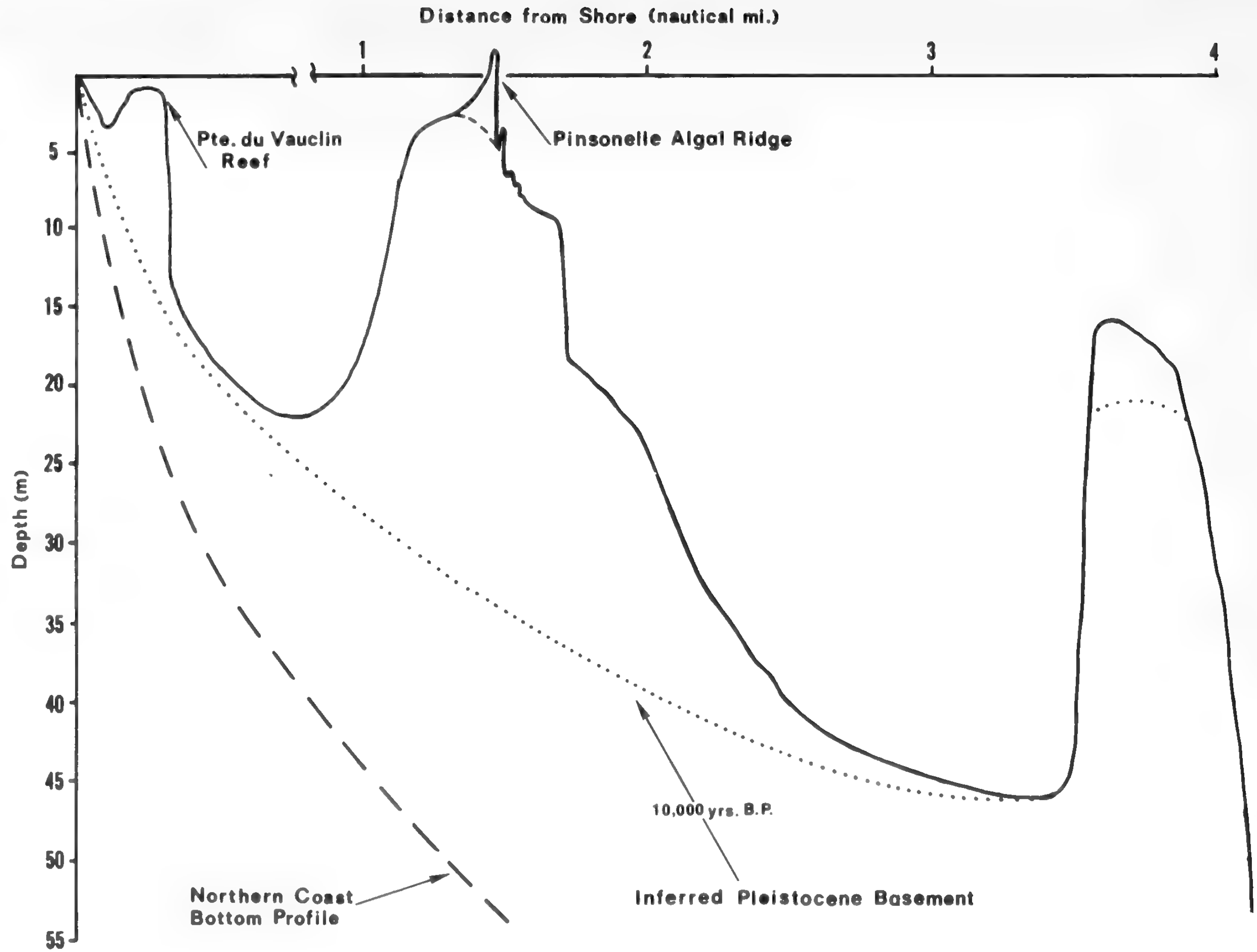
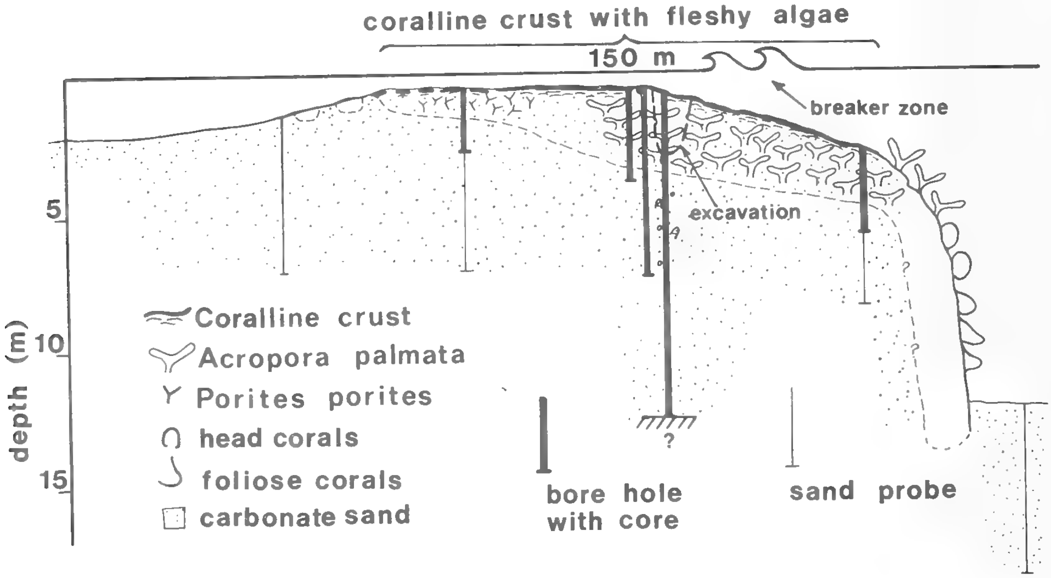


Fig. 2. Bottom profile (see V--P on Fig. 1 for location) across eastern shelf showing inner and outer reef systems and the shelf edge feature (Macintyre, 1972; Adey and Macintyre, in prep.). The sub bottom profile inferred is discussed in the text. The northern coast profile was taken off Point Chateauque.

Fig. 3. Section across Vauclin Point reef, V on figure 1.



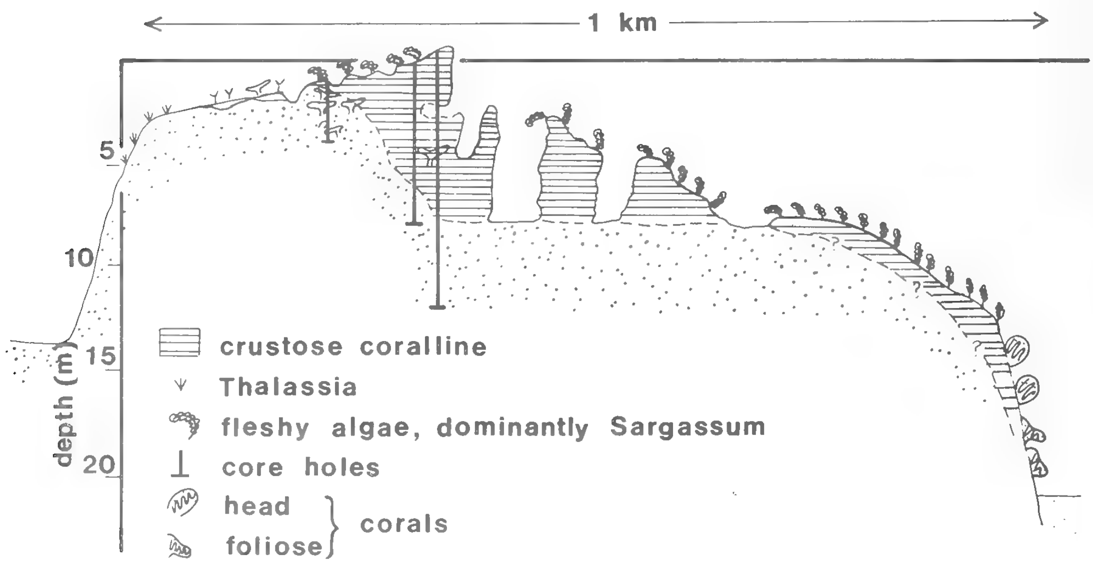


Fig. 4. Section across Pinsonelle algal ridge on the outer reef system, P on figure 1.

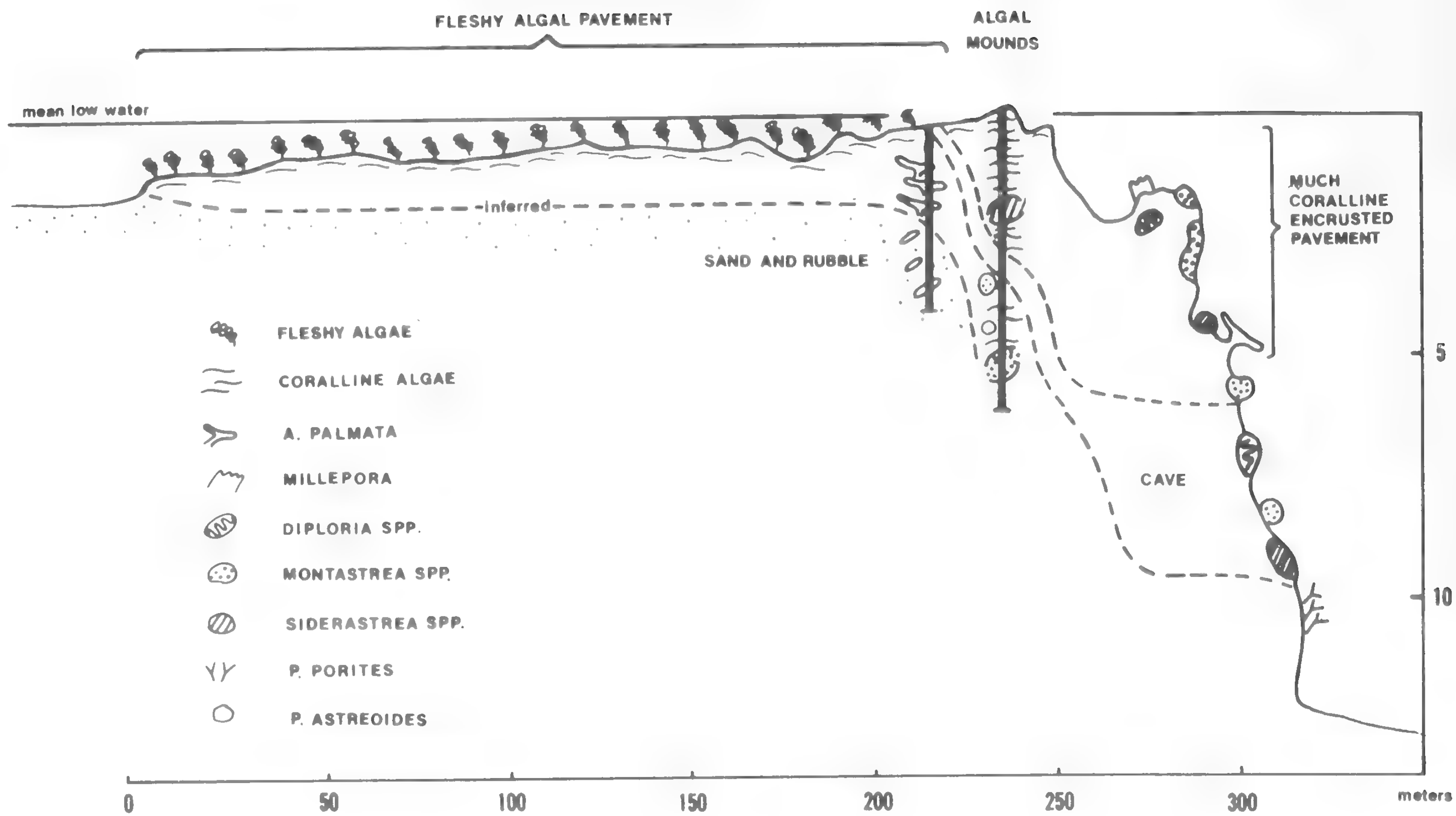


Fig. 5. Section across Ramville Island reef, R on figure 1.

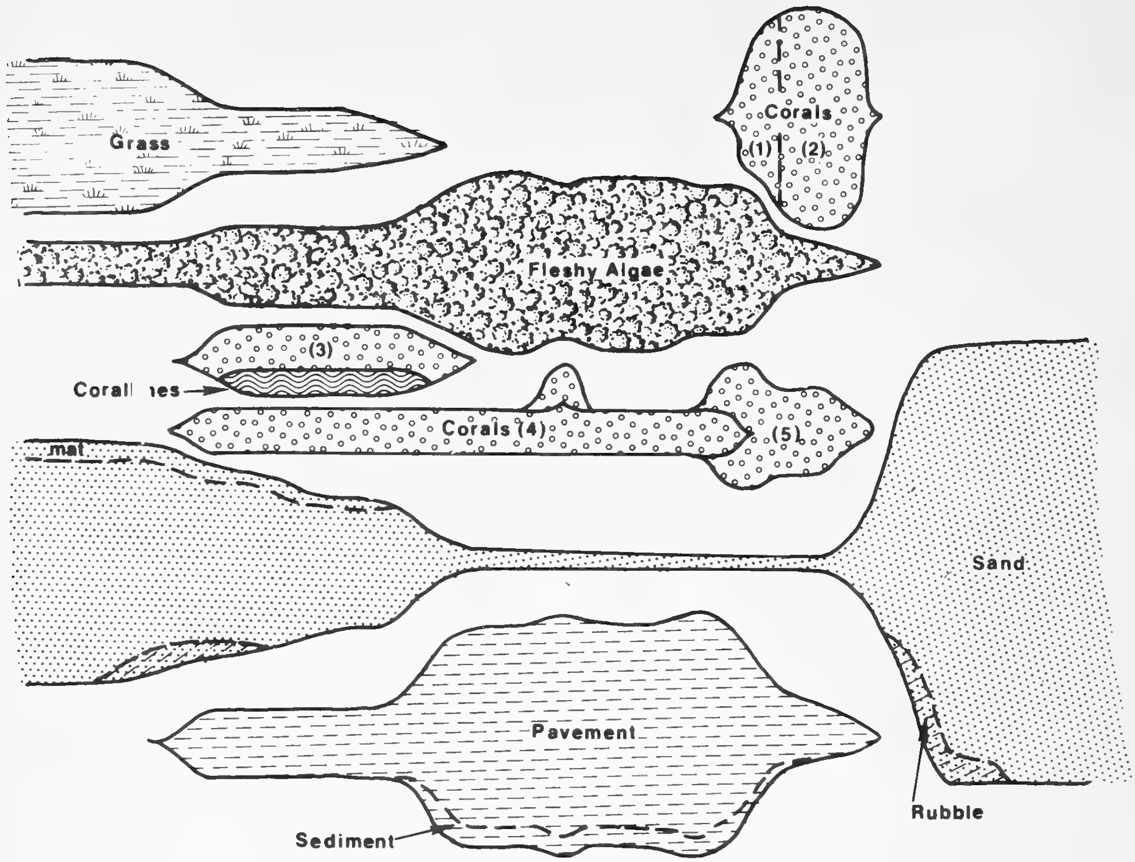
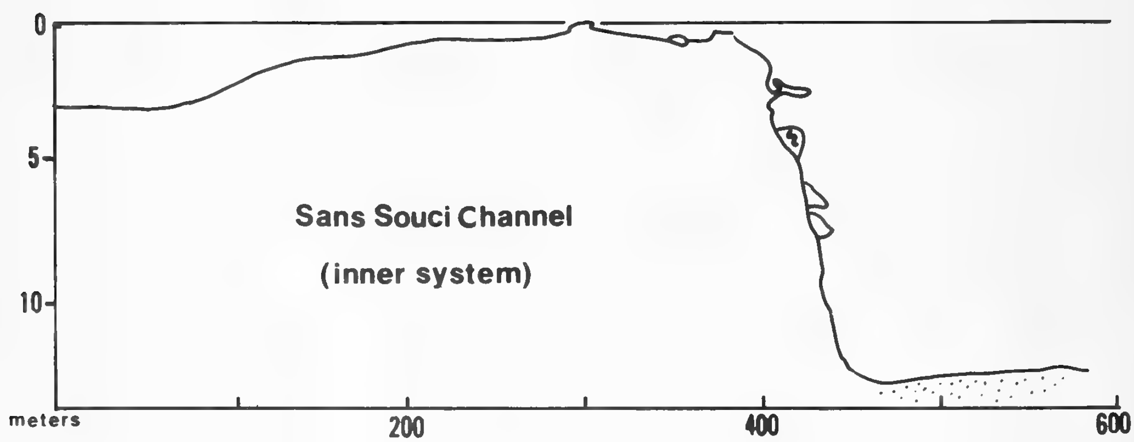


Fig. 6.



Profile and surface zonation across San Souci Channel reef. Section S on figure 1. Corals: (1) Porites porites. (2) Montastrea annularis, Diploria clivosa, D. strigosa. (3) P. furcata. (4) P. astreoides, Dichocoenia stokesii, Manicina areolata, Favia fragum, M. annularis. (5) Millepora spp., Acropora palmata. Corallines: Neogoniolithon westindianum. Pavement: grazed coralline encrusted. Mat: algal stabilized sediment.

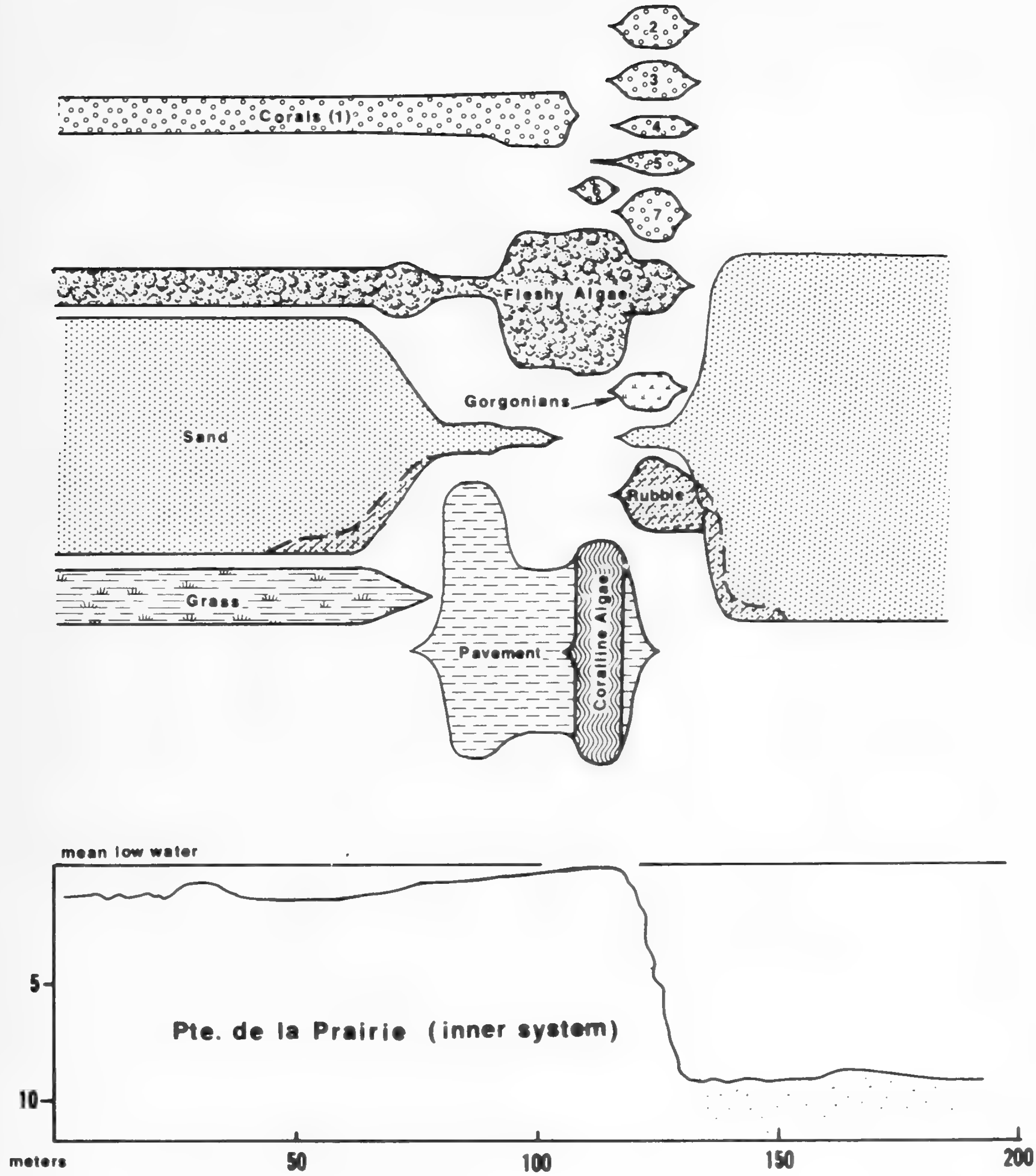


Fig. 7. Profile and zonation across Pte. de la Prairie reef. Section Sp on figure 1. Corals: (1) *Porites porites*, *P. astreoides*, *Siderastrea siderea*, *S. radians*, *Manicina areolata*, *Favia fragum*. (2) *Diploria* spp. (3) *Montastrea annularis*. (4) *Acropora palmata*. (5) *P. astreoides*. (6) *Millepora squarosa*. (7) *P. porites*, *P. furcata*, *Mycetophyllia* sp., *Agaricia* sp.

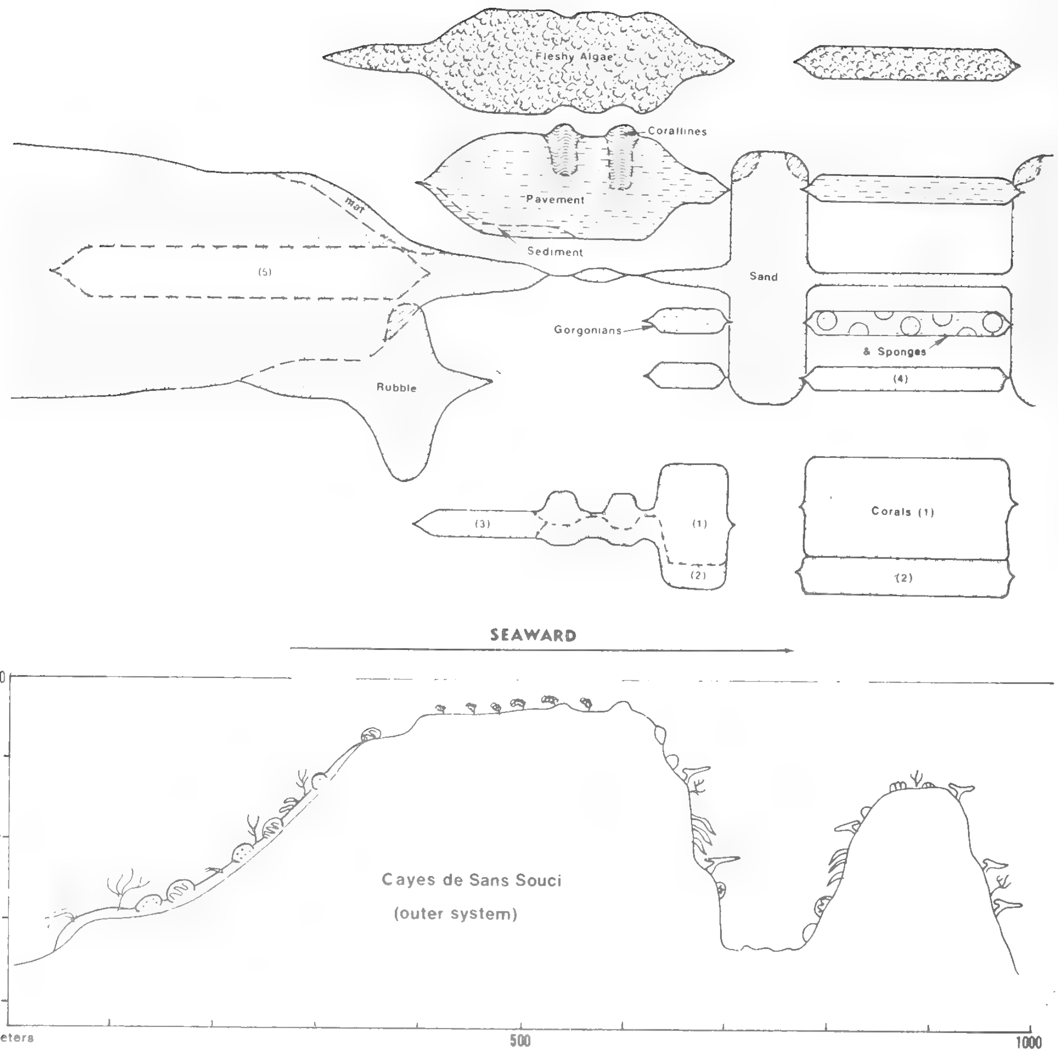


Fig. 8. Profile and zonation across Cayes de San Souci. Section C on figure 1. Corals: (1) Diploria labyrinthiformis, D. clivosa, Millepora spp., Montastrea annularis, Agaricia agaricites. (2) Isophyllia sp. Mycetophyllia sp., Porites astreoides. (3) Favia fragum, Diploria sp., Siderastrea siderea, P. astreoides. (4) Acropora palmata. (5) deep reef community growing on carbonate spurs. Corallines: Lithophyllum congestum, Neogoniolithon sp.

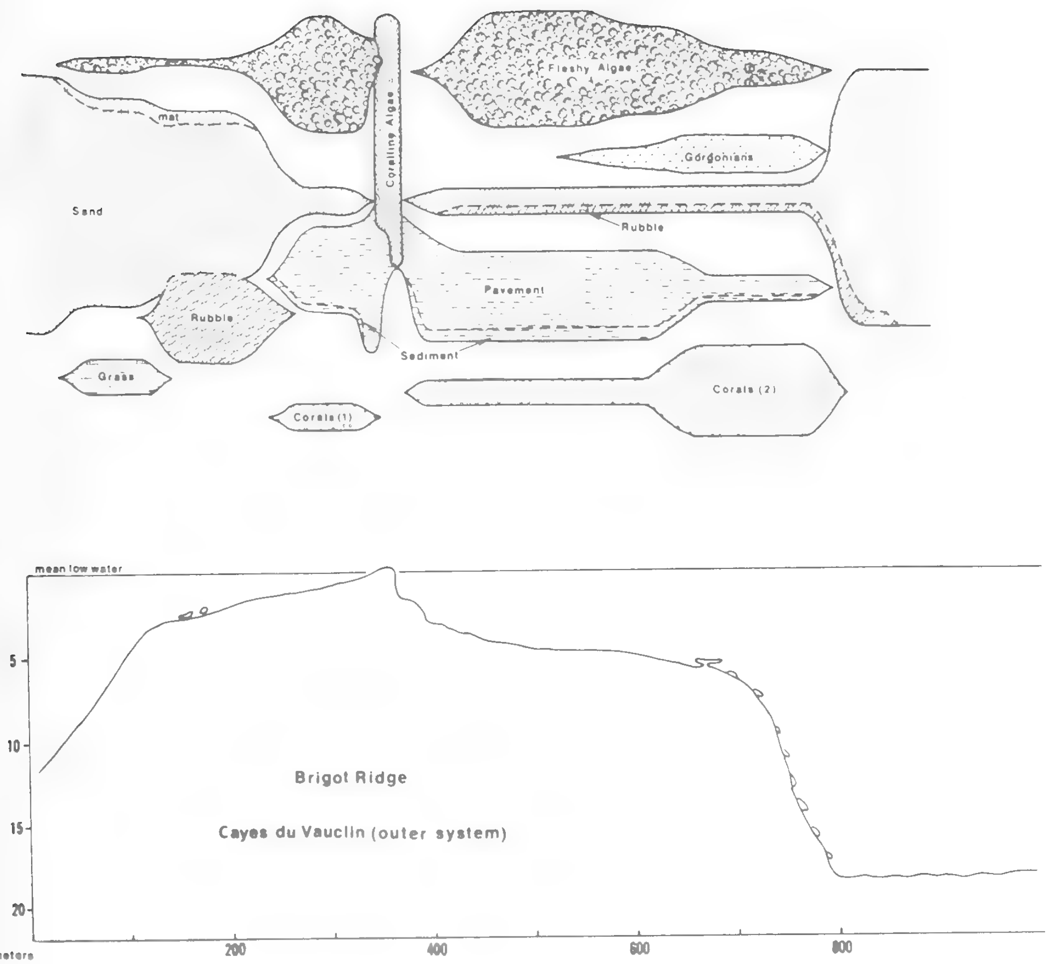


Fig. 9.

Profile and zonation, Cayes de Vauclin (Brigot). Marked Brigot Ridge on figure 1. Corals: (1) Millepora sp. and Porites astreoides. (2) Millepora sp., Diploria clivosa, upper section; Siderastrea siderea, Montastrea annularis, Isophyllia sp., lower section. Coralline algae, about 75% living - Lithophyllum congestum, Neogoniolithon megacarpum, Neogoniolithon spp., Porolithon pachydermum.

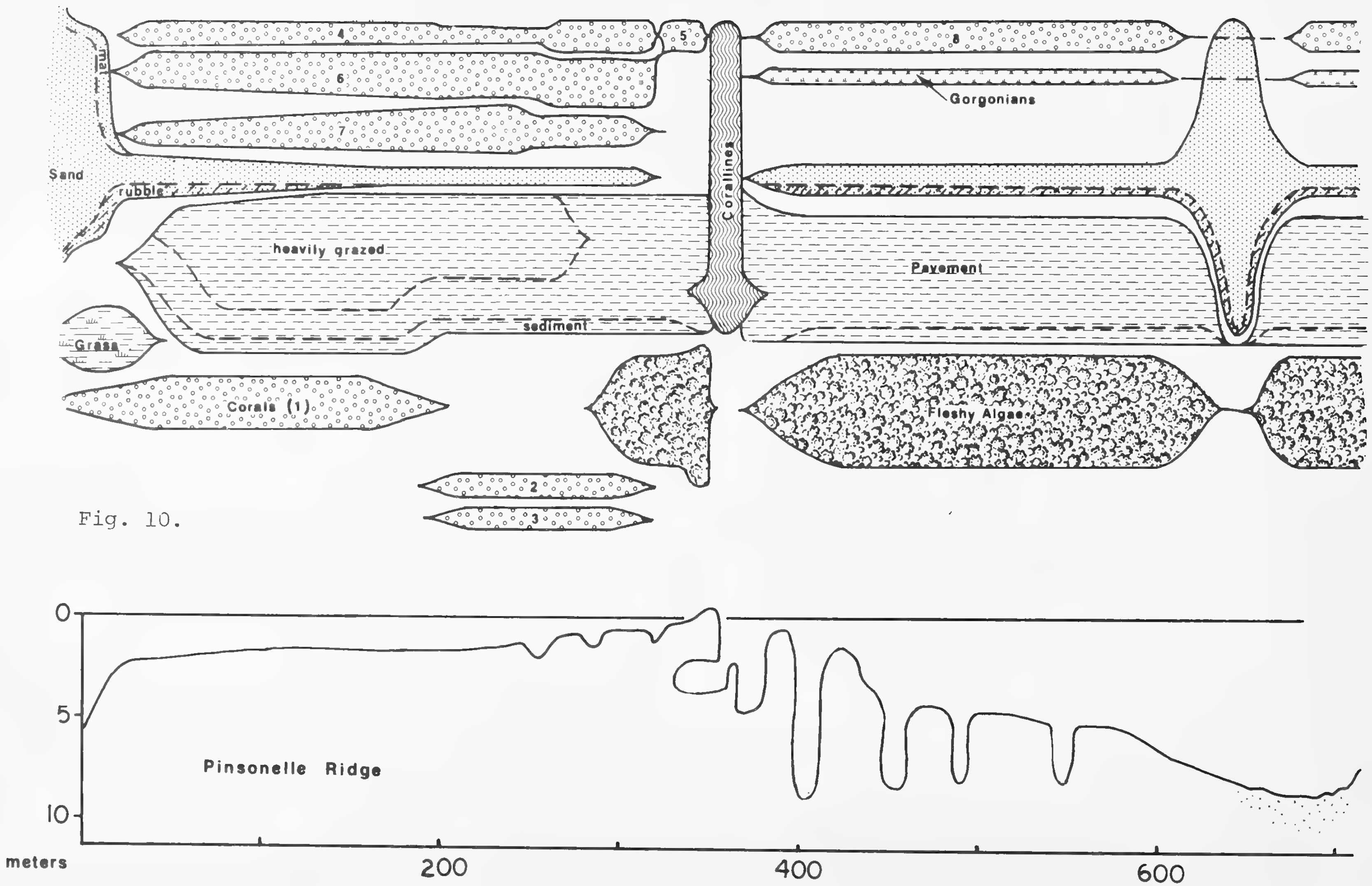


Fig. 10.

Profile and zonation, Pinsonelle algal ridge. (1) Acropora palmata. (2) Millepora spp. (3) Montastrea annularis. (4) Agaricia agaricites, Favia fragum, Diploria clivosa. (5) Siderastrea siderea, Diploria clivosa, Porites astreoides. (6) Porites astreoides. (7) P. porites. (8) Millepora alcicornis, F. fragum, D. clivosa. Corallines: Porolithon pachydermum, Lithophyllum congestum, Neogoniolithon megacarpum. Fleshy algae: dominantly Dictyopterus and Sargassum

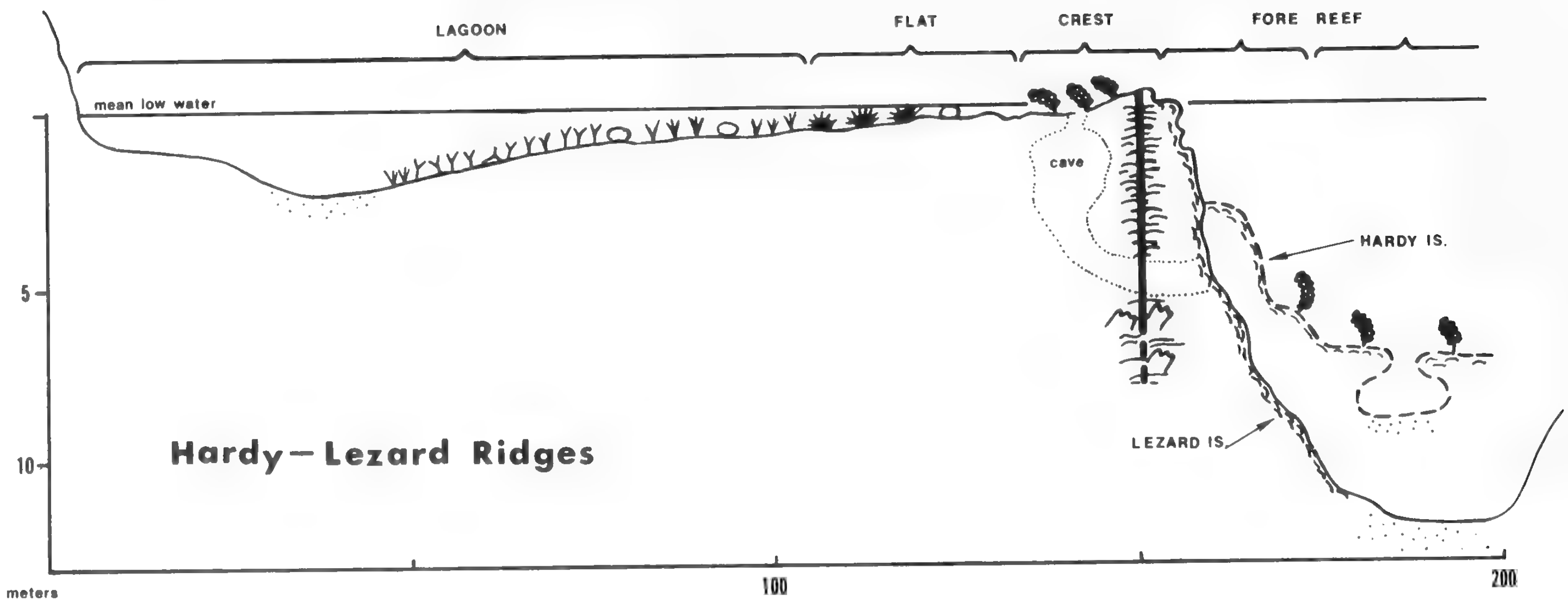


Fig. 11. Composite section across bench algal ridges at Hardy and Lezard Is., showing location and composition of core drilled at Lezard. H and L on figure 1. Lagoon - sand, Porites spp. and sea grasses. Flat - heavily grazed coralline encrusted pavement, abundant Diadema and Porites astreoides. Crest - abundant fleshy algae, especially Hypnea and Laurencia. Fore reef - upper section, coralline pavement, often heavily grazed, scattered corals; lower section, fleshy algal pavement with sand channels. Symbols as in Fig. 5.

231-339 O - '77 - 16

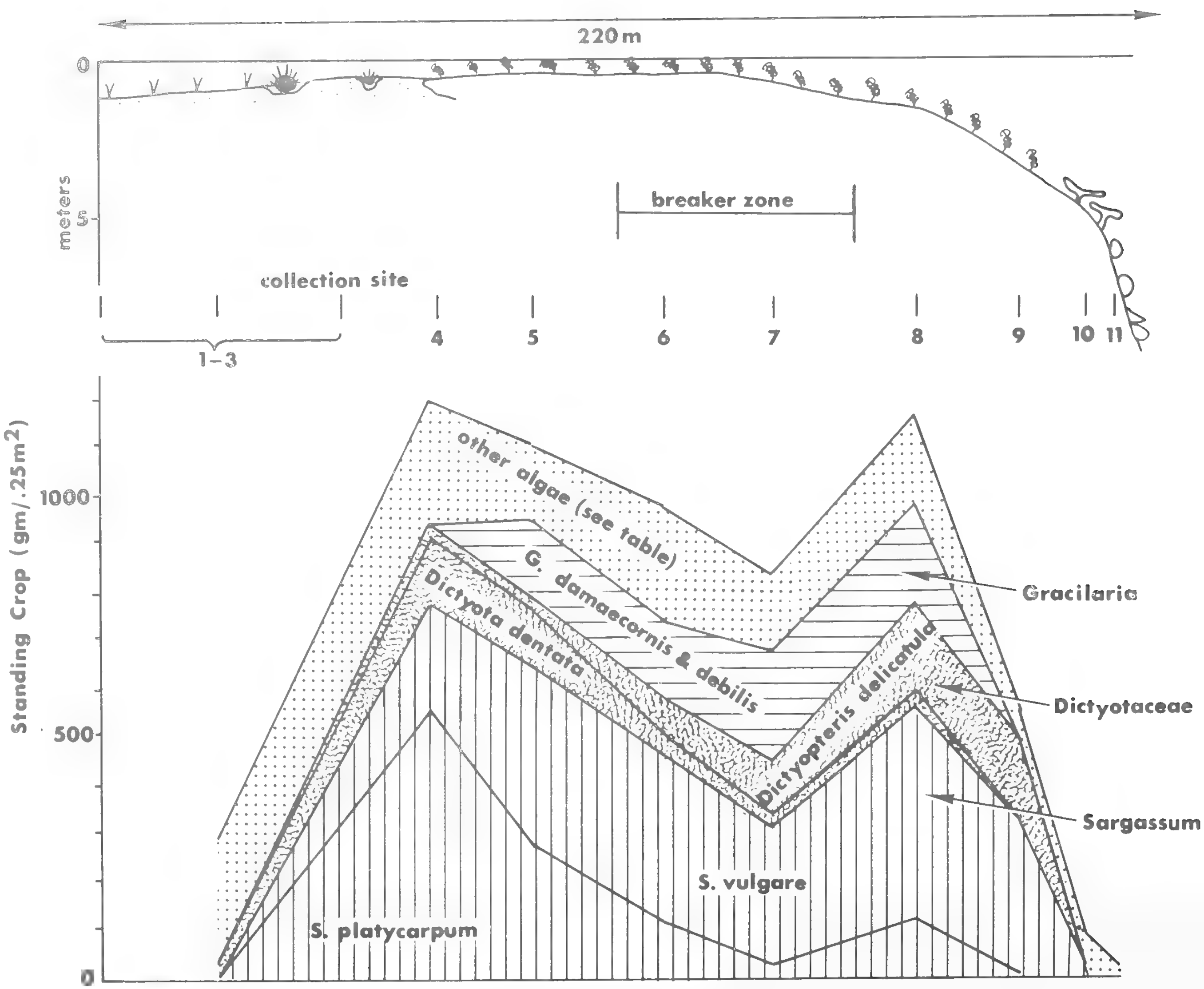


Fig. 12. Dominant species of benthic fleshy algae and standing crop on Vauclin Point algal pavement.

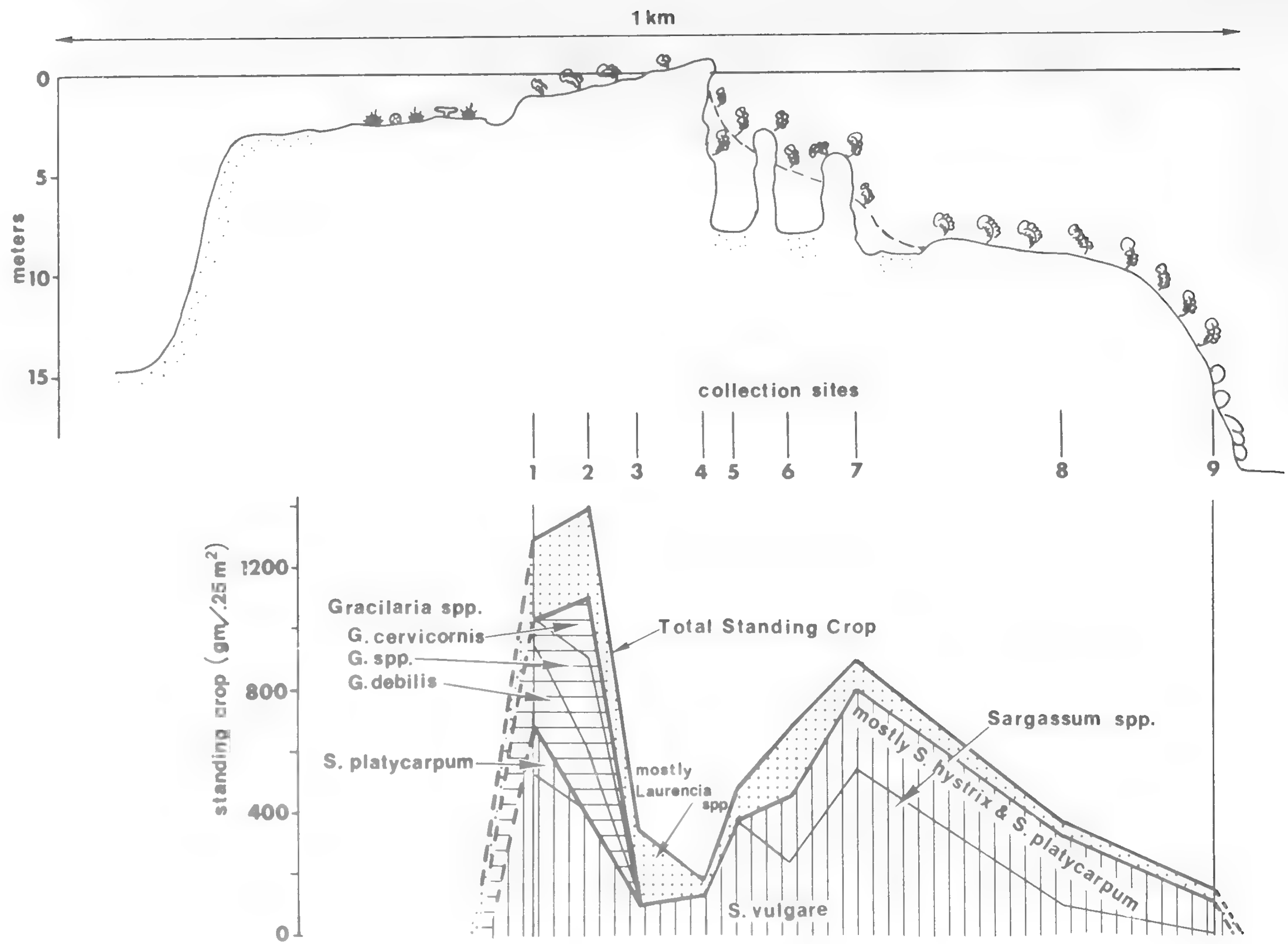


Fig. 13. Dominant species of benthic fleshy algae and standing crop on Pinsonelle algal ridge.

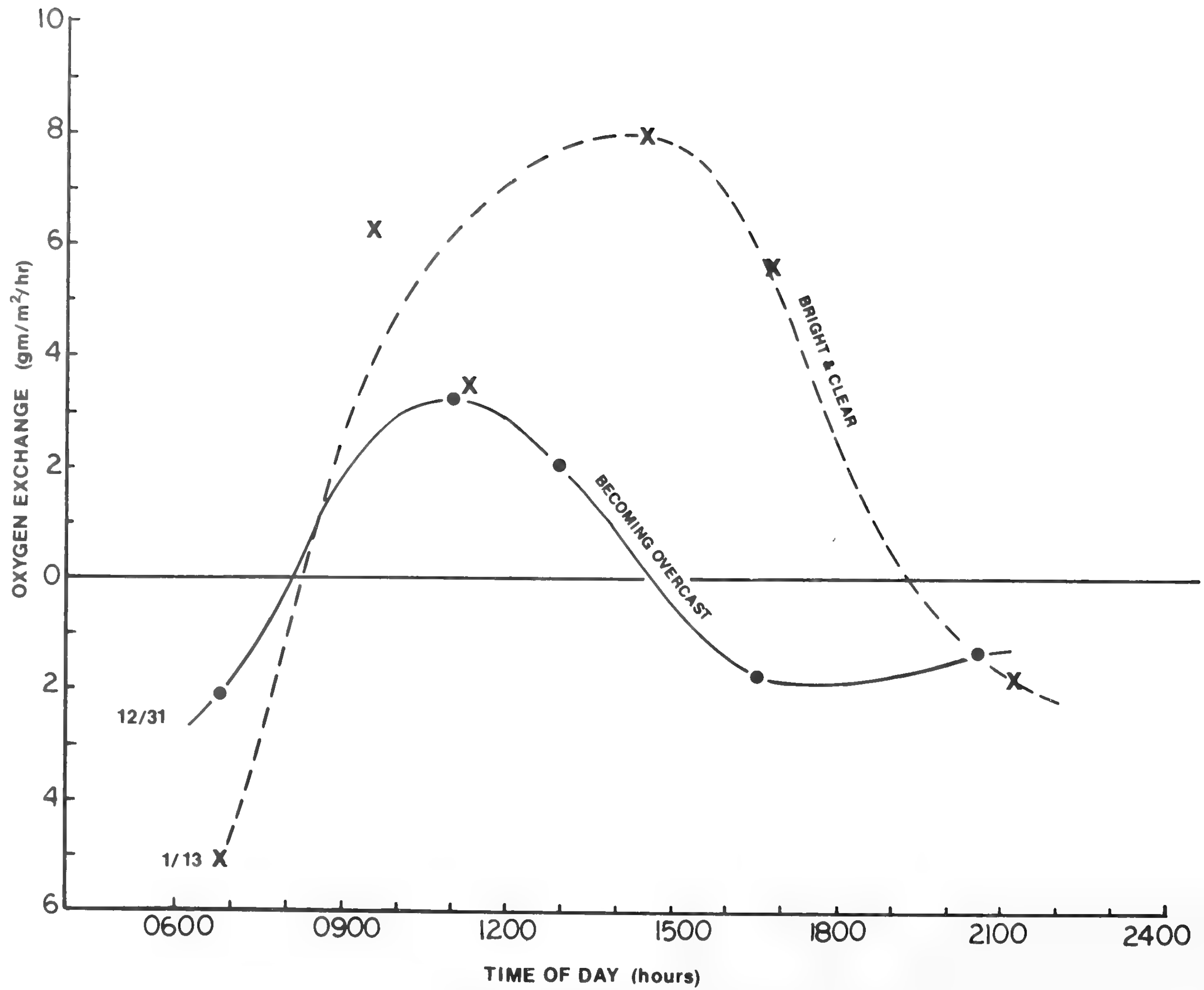


Fig. 14. Rate of oxygen exchange between reef surface and water for two different days on Vauclin Point inner algal pavement.

Table 1. Corals Recorded from the Reefs of Martinique

ANTHOZOA

Scleractinia

Acroporidae
Acropora cervicornis
A. palmata

Agariciidae[1]
Agaricia agaricites

Poritidae
Porites astreoides
P. porites
P. divaricata
P. furcata

Siderastreidae
Siderastrea radians
S. siderea

Faviidae
Montastreinae[2]
Montastrea annularis
M. cavernosa

Faviinae
Favia fraguum
Diploria strigosa
D. clivosa
D. labyrinthiformis
Manicina areolata
Colpophyllia natans[3]

Rhizangiidae
Astrangia solitaris
Phyllangia americana

Oculinidae
Oculina valenciennesi

Trochosmilidae
Meandrina meandrites
Dendrogyra cylindrus
Dichocoenia stokesii

Mussidae
Scolymia lacera
Mussa angulosa
Isophyllastrea rigida
Isophyllia sinuosa
Mycetophyllia lamarckiana

Cariophylliidae
Eusmilia fastigata

HYDROZOA

Milleporina

Milleporidae
Millepora alcicornis[4]
M. squarrosa
M. complanata

Stylasterina

Stylastridae
Stylaster roseus

1. Three additional morphologies were observed.
2. *Solenastrea bournoni* was observed by P. W. Hummelinck but we did not encounter it.
3. At least three different morphologies were observed.
4. Extremely variable morphologies were encountered including a long, thin, fingered variety and a wrinkled vase-forming variety, apparently ecovariants.

Table 2. Benthic macro algae, Pte. Vauclin algal pavement, 0.25m^2 quadrats; site locations shown in figure 12. Fractions to left in columns indicate number of quadrats in which species appeared/total quadrats collected; figure to right indicates mean net weight in grams (less than 0.1 gm not indicated).

SPECIES	SITE 1,2,3	4	5	6	7	8	9	10	11
CHLOROPHYTA									
Cladophoraceae									
Chaetomorpha sp.	2/3 0.1	1/3	2/6		1/3				
Cladophora sp.		1/3	1/6				1/2		
Dasycladaceae									
Acetabularia spp.			1/6						
Neomeris annulata	1/3								
Valoniaceae									
Anadyomene stellata	1/3	3/3 0.1	3/6 0.3	2/3	1/3 2.2		1/2		
Struvea	1/3		1/6	1/3	1/3				
Cladophoropsis membranacea	1/3 7.1								
Ernodesmis spp.	2/3 0.8	1/3 0.3	4/6 0.5	1/3	1/3		1/2		
Valonia ventricosa	2/3 0.1		1/6 0.1						
Dictyosphaeria cavernosa	3/3 6.6	3/3 8.4	5/6 4.1	2/3 4.0	2/3 1.7	1/3 3.4	1/2 1.4		
Chamaedoris penicillium		3/3 4.4	6/6 3.9	2/3 1.3	2/3 4.3	2/3 3.3			
Caulerpaceae-Bryopsidaceae									
Bryopsis pennata			1/6	1/3					1/1
Caulerpa spp.			1/6 3.1			1/3 1.3			

C. prolifera	2/3 1.8		1/6 1.8						
C. sertularioides	2/3 0.2		3/6 1.0		1/3 6.0				
C. floridana		1/3 0.5							
C. verticillata						1/3			
C. peltata			1/6 0.5						
C. vickersiae		1/3	1/6	3/3	3/3				
C. cupressoides	1/3 0.1		1/6 0.5						
Codiaceae									
Codium repens	2/3 0.9				2/3 11.0				
C. taylori	1/3 5.0	1/3 27	2/6 1.4	2/3 11		1/3 2.7			
C. intertextum				1/3 1.7		1/3 0.7			
Codium spp.			1/6 6.6						
Avrainvillea nigricians	2/3 17.8								
A. rawsoni	2/3 9.3	1/3 10.0						1.1 84	1/1 20
Udotea flabellum	1/3 0.5								
Halimeda spp.	1/3 9.8								
H. discoidea	2/3 2.1	2/3 7.2	4/6 7.7	2/3 10.		3/3 3.5			
H. incrassata	1/3 9.0								
H. simulans	1/3 0.5								
Penicillus capitatus	3/3 13.0	1/3 0.9							
P. dumetosus	1/3 1.0	2/3 2.1							
Thalassia	3/3 70	1/3 16							
Syringodium	2/3 18.5								
PHAEOPHYTA									
Colpomenia sinuosa	1/3 5.3	1/3 0.3		1/3 0.1	1/3				
Dictyotaceae									
Dictyota spp.		1/3 1.5	3/6 1.4			2/3 2.3	1/2 1.5		
D. dentata	2/3 0.5	3/3 133	6/6 117	3/3 41	3/3 24	3/3 31	2/2 11.0		

Table 2 (cont'd.)

D. divaricata	3/3 69	1/3 23	1/6 3.7	2/3 13.	2/3 11	1/3 1.2	2.2 1.2		
Dilophus quiniensis	1/3 12.8		1/6 0.8						
Dictyopteris membranacea	2/3 0.1	1/3 0.3	5/6 1.3		1/3 3.0	3/3 7.5	2/2 38		
D. delicatula	1/3	3/3 28	6/6 28	3/3 67	3/3 108	3/3 56	2/2 136	1/1	
D. justii	1/3 0.5	2/3 22	3/6 8.2		1/3 11	2/3 11			
Spatoglossum schroederi	1/3	3/3 1.0	2/6 2.3	1/3 1.7		1/3 0.5	1/2 2.3		
Lobophora variegata		1/3 1.9	5/6 17	2/3 1.0	2/3 22	3/3 16	2/2 2.5		
Sargassaceae									
Sargassum platycarpum		3/3 565	5/6 292	2/3 109	2/3 23	2/3 122			
S. vulgare		3/3 224	6/6 368	3/3 348	3/3 294	3/3 448	2/2 330		
RHODOPHYTA									
Nemalionales									
Asparagopsis hamifera				3/3			1/2		
Liagora spp.	1/3	1/3	1/6	1/3 0.5					
Galaxaura spp.	2/3	1/3 1.7	3/6 1.4		1/3				
G. oblongata			1/6	2/3 1.5	1/3	1/3			
G. marginata		3/3 6.2	4/6 9.0	2/3 2.3	1/3				
G. subverticillata		1/3 3.5		1/3 1.2	1/3				
G. squalida		1/3	2/6 2.5						
Gelidiales									
Wurdemania miniata	2/3		1/6 0.8		1/3	1/3	1/2		
Gelidiella acerosa	2/3 5.8	2/3 5.1	6/6 4.6	2/3 2.2	1/3 0.5				
Pterocladia americana	1/3					1/3	2/2		
Gelidium pusilum	1/3	1/3 0.3	4/6	3/3	2/3	2/3	2/2		
Rhodymeniales									
Botryocladia pyriformis		2/3	5/6 1.0	2/3 2.5	3/3 3.7	3/3 7.0	2/2 1.2		

B. occidentale					1/3 0.8				
Champia parvula		2/3		1/3 1.0	1/3				
C. salicornoides	1/3			1/3 0.8					
Coelothrix irregularis		1/3 5.0							
Chrysymenia sp.							1/2		
Cryptonemiales									
Halymenia spp.					2/3 0.5				
Jania spp.	1/3 1.4	1/3	3/6	1/3		1/3		1/1	1/1
J. capillacea				1/3		1/3			
J. pumila						1/3			
Amphiroa spp.			1/6 0.2		1/3	2/3 0.8			
A. fragillissima		1/3		1/3	1/3				
A. tribulus						2/3 1.4	1/2 3.5		
A. rigida						1/3			
Gigartinales									
Gracilaria spp.	1/3 0.5	3/3 8.9	4/6 5.0			1/3 1.1			
G. ferox	1/3	3/3 5.3	3/6 6.3	3/3 42	2/3 25	3/3 45	2/2 20		
G. debilis			6/6 154	2/3 157	3/3 97	3/3 212	1/2 1.4		
G. damaecornis		1/3 26	1/6 10	2/3 9.5	2/3 55	1/3 16			
G. mammillaris		1/3	2/6 1	1/3 1.4	2/3 15	3/3 18	1/2 1.5		
G. cuneata		1/3 4.1	2/6 1.9	1/3 6.8	2/3 4.5	2/3 14	2/2 11		
Hypnea spinella				2/3 0.1					
H. musciformis	1/3	1/3	1/6						
Eucheuma spp.		2/3 3.6	3/6 3.7	3/3 10	2/3 4.9				
Meristotheca floridana			1/6	1/3 1.4	1/3 0.2	1/3			
Ceramiales - Ceramiaceae									
Callithamnion spp.			1/6			1/3			
Antithamnion spp.				1/3					
Wrangelia penicillata			1/6	2/3 6.8	2/3				
Ceramium nitens			1/6 0.9						

Table 2 (cont'd.)

Centroceras clavulatum		3/3	3/6 0.2	2/3 1.3	1/3 6.3				
Spyridia aculeata				1/3 4.6					
Griffithsia globulifera	1/3	3/3	3/6	3/3	2/3 0.8	1/3			
Spermothamnion spp.	1/3	1/3	2/6	2/3	2/3 0.8				
Ceramiales - Dasyaceae									
Heterosiphonia				1/3	1/3				
Ceramiales - Delesseriaceas									
Nitophyllum spp.					1/3	1/3	1/2		
Ceramiales - Rhodomelaceae									
Polysiphonia spp.	1/3	1/3	1/6						
Bryothamnion triquetium	1/3 1.6	1/3 6.0							
Lophosiphonia spp.			1/6						
Acanthophora muscoides				1/3 3.5	1/3 2.3				
A. spicifera	1/3 0.4	1/3			1/3				
Digenia simplex	3/3 58.6	1/3	1/6						
Laurencia spp.						1/3 5.0	1/2 2.0		
L. intricata			2/6 0.1	1/3	1/3	2/3 0.6			
L. corallopsis		3/3 3.3	1/6 0.8	1/3 5.0		1/3 1.3			
L. poitei	1/3 1.0	1/3 13	4/6 7.8	1/3 10	1/3				
L. papillosa	3/3 3.9	3/3 5.2	4/6 11	2/3 11.9	1/3 7.6				
L. obtusa	1/3	1/3	1/6 1.0	2/3 14	2/3 13				
L. gemmifera	1/3 0.8	2/3 16.6	1/6 1.4	3/3 21	2/3 50				
Chondria spp.		1/3	1/6						
Enantiocladia duperreyi	2/3 4.6	1/3 18	5/6 8.9						
Vidalia obtusiloba	1/3 0.1		1/6 3.7						
Total mean wgt. gm/0.25m^2	341	1209	1108	927	809	1033	565	84	20
Total number of species	55	58	68	53	51	41	25	3	3
Total sp. with wgt 1gm/0.25m^2	23	32	36	34	25	24	16	1	1
Total sp. occurring	7	15	6	10	6	10	11		

Table 3.

Martinique Fish, Grouped by Relative Abundance

Typical habitat: FR(fore reef), AP(algal pavement), BR(back reef).
(T) indicates uncertainty in identification.

Class I

			FR	AP	BR
1	Jenkinsia lamprotaenia (T)	Dwarf Herring		x	x
2	Holocentrus ascensionis	Longjaw Squirrelfish	x		x
3	H. rufus	Common Squirrelfish	x		x
4	Atherinomorus stipes	Hardhead Silversides		x	x
5	Allanetta harringtonensis	Reef Silversides			x
6	Planktivorous Carangid (T)	(on Pte. du Vauclin)	x		
7	Ocyurus chrysurus	Yellowtail Snapper	x		x
8	Haemulon chrysargyreum	Smallmouth Grunt	x		x
9	H. sciurus	Bluestriped Grunt	x		x
10	Mulloidichthys martinicus	Yellow Goatfish	x		x
11	Pempheris schomburgki	Copper Sweeper	x		x
12	Kyphosus sectatrix (T)	Bermuda Chub	x		
13	Eupomacentrus fuscus	Dusky Damselfish	x	x	x
14	E. partitus	Bicolor Damselfish	x	x	x
15	Microspathodon chrysurus	Jewelfish	x		x
16	Abudefduf saxatilis	Sergeant Major	x	x	x
17	Chromis multilineatus	Grey Chromis	x	x	x
18	Halichoeres bivittatus	Slippery Dick	x	x	x
19	H. radians	Puddingwife	x	x	x
20	H. maculipinna	Clown Wrasse		x	
21	Thalassoma bifasciatum	Bluehead Wrasse	x	x	x
22	H. poeyi	Blackear Wrasse		x	
23	Sparisoma rubripinne	Yellowtail Parrotfish		x	
24	S. radians	Bucktooth Parrotfish		x	
25	Scarus croicensis	Striped Parrotfish	x		x
26	Ophioblennius atlanticus	Redlip Blenny	x	x	x
27	Labrisomus nuchipinnis et al.	Hairy Blenny		x	
28	Malacoctenus aurolineatus	Goldline Blenny	x	x	x
29	Malacoctenus macropus	Rosy Blenny	x	x	x
30	Malacoctenus erdmanni	Imitator Blenny	x	x	x
31	other Malacoctenus spp.		x	x	x
32	Acanthurus coeruleus	Blue Tang	x		x
33	A. bahianus	Ocean Surgeonfish	x	x	x
34	A. chirurgus	Doctorfish	x	x	x
35	Coryphopterus glaucofrenum	Bridled Goby		x	
36	C. hyalinus et al. (T)	Glass Gobies	x		

Table 3 (con't.)

Class II

			FR	AP	BR
37	Synodus intermedius	Sand Diver	x		x
38	Aulostomus maculatus	Trumpetfish	x		x
39	Adioryx coruscus	Reef Squirrelfish			x
40	Myripristes jacobus	Blackbar Soldierfish			x
41	Cephalopholis fulva	Coney	x		x
42	Alphestes afer	Mutton Hamlet		x	
43	Hypoplectrus puella	Barred Hamlet	x		x
44	Serranus tigrinis	Harlequin Bass			
45	Priacanthus cruentatus	Glasseye Snapper	x		x
46	Lutjanus griseus	Grey Snapper	x		x
47	L. apodus	Schoolmaster	x		x
48	Haemulon flavolineatum	French Grunt	x		x
49	H. plumieri	White Grunt	x		x
50	Eupomacentrus planifrons	Yellow Damselfish, 3-spot	x		
51	E. variabilis	Cocoa Damselfish	x		
52	E. leucostictus	Beaugregory			x
53	Doratonotus megalepis	Dwarf Wrasse		x	
54	Hemipteronotus splendens	Green Razorfish		x	
55	Sparisoma viride	Stoplight Parrotfish	x		x
56	S. chrysopterum	Redtail Parrotfish	x	x	x
57	Gnatholepis thompsoni	Goldspot Goby	x	x	x
58	Gobiosoma evelynae	Sharknose Goby		x	
59	Balistes vetula	Queen Triggerfish	x		x
60	Cantherhines pullus	Tail-Light Filefish	x		x
61	Canthigaster rostrata	Sharpnose Puffer	x		x
62	Diodon holocanthus	Spiny Puffer		x	

Class III

			FR	AP	BR
63	Synodus synodus	Rockspear			x
64	Echidna catenata	Chain moray		x	
65	Strongylura spp.	Needlefish		x	x
66	Hemiramphus brasiliensis	Ballyhoo			x
67	Adioryx vexillarius	Dusky Squirrelfish			x
68	Sphyraena barracuda	Great Barracuda	x		
69	Epinephelus guttatus	Red Hind	x	x	x
70	E. adscensionis	Rock Hind		x	
71	Gramma loreto	Royal Gramma	x		
72	Rypticus sapnoaceous	Soapfish	x		x
73	Caranx ruber	Barjack	x		x
74	Trachinotus goodei	Palometa	x		
75	Scomberomorus regalis	Cero	x		
76	S. cavalla	King Mackeral	x		
77	Lutjanus mahogony	Mahogony Snapper	x		x
78	Haemulon aurolineatum	Tomtate			x
79	Odontoscion dentax	Reef Croaker		x	x
80	Equetus acuminatus	Cubbyu		x	x
81	Pseudopeneus maculatus	Spotted Goatfish			x
82	Gerres cinereus (T)	Yellowfin mojarra		x	x
83	Bothus lunatus	Peacock Flounder			x

Table 3 (con't.) Class III (con't.)

			FR	AP	BR
84	Scorpaena plumieri	Spotted Scorpionfish		x	
85	S. grandicornis	Grass Scorpionfish		x	
86	Chaetodon capistratus	Foureye Butterflyfish	x	x	x
87	C. striatus	Banded Butterfly	x		x
88	Bodianus rufus	Spanish Hogfish	x		
89	Hemipteronotus novacula	Pearly Razorfish		x	
90	Sparisoma aurofrenatum	Redband Parrotfish	x		x
91	Lactophryis triqueter	Smooth Trunkfish	x		x
92	Sphaeroides greelyi	Caribbean Puffer			x
93	S. spengleri	Bandtail Puffer			x
94	Diodon hystrix	Porcupinefish	x		x

Class IV

95	Dasyatis americana	Stingray
96	Gymnothorax moringa	Spotted Moray
97	G. vicinus	Purplemouth Moray
98	Apogon maculatus	Flamefish
99	Dactylopteris volitans	Flying Gurnard
100	Scarus vetula	Queen Parrotfish

Class V

101	Trachinotus falcatus	Permit
102	Caranx hippos	Crevalle Jack
103	Pempheris poeyi	Shortfin Sweeper
104	Pomacanthus paru	French Angelfish
105	Eupomacentrus mellis	Honey Gregory
106	Halichoeres garnoti	Yellowhead Wrasse

Lagoon, Sand, Grass

Near the Reef

107	Ophichthus ophis	Spotted Snake Eel
108	Myrichthys oculatus	Goldspotted Snake Eel
109	Hippocampus reidi	Slender Seahorse
110	Mugil curema	Mullet
111	Hypoplectrus nigricans	Black Hamlet
112	Monocanthus ciliatus	Fringed Filefish
113	M. tuckeri	Slender Filefish
114	Antennarius multiocellatus	Longlure Frogfish

Cryptic within carbonate pavement

115 Stathmonotus spp.
116 Enneanectes pectoralis

A. palmata (Fajou – Union Island); A. palmata/coralline-Millepora (Union Island – Goyave); fleshy algal pavement (Goyave – Lezard Island)

	Fajou (G)	Middle Reef (A)	Fishtail Cay (A)	Union Island (Gr)	Palm Island (Gr)	World's End (Gr)	Horseshoe Reef (Gr)	St. Marie (G)	St. Barts	Goyave (G)	Nevis	Ramville Island(M)	Vauclin Point (M)	Lezard Island (M)
Scarus vetula	∷	∷	∷	⠿	⠿	⠿	⠿	⠿	⠿	∷		(••)	(••)	
Sparisoma viride	∷	∷	⁙	∷	⠿	⠿	⠿	⠿	⁙	⁙	(∷)	(∷)	(∷)	(∷)
Halichoeres garnoti	∷	∷	∷	∷	•••	•••	∷		•••					
Chromis cyanea	⁙	⁙		•••										
Holacanthus tricolor		••		∷	∷		⁙							
H. ciliaris			••				⁙		••					
Scarus taeniopterus							••							
S. coelestinus							•••	••	•••					
S. guacamaia				••			••							
Hypoplectrus chlorosus	(•)		••				∷	•						
Pomacanthus paru									•••					
Sparisoma rubripinne	∷	∷	∷	⁙	∷	∷	∷	⠿	⠿	⠿	⠿	⠿	⠿	⠿
Halichoeres poeyi	•••			••	•••			∷	∷	⁙	⁙	⁙	⁙	∷
Sparisoma radians										∷		⁙	⁙	
Doratonotus megalepis									••		∷	∷	∷	
Alphestes afer											∷	∷	∷	
Abudefduf taurus				•••	•••									⁙

KEY

(G) Gaudeloupe
(A) Antigua
(Gr) Grenadines
(M) Martinique

		no/hr
⠿	Abundant (large % of biomass)	50
⁙	Abundant (small % of biomass)	50
∷	Always Seen	10-50
•••	Frequently Seen	2- 9
••	Occasional	1
•	Rare	1

Table 4. Fish species contrasting most in relative abundance on different reef types. Parentheses indicate the presence of a species on small patches of A. palmata near or surrounded by coralline-Millepora pavement.

ATOLL RESEARCH BULLETIN
NO. 219

ISLAND NEWS AND COMMENT

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.

May 1977

ISLAND NEWS AND COMMENT

Again we have material on hand for a substantial News and Comment number, but have not had time to edit much of it for publication. We do not want to delay publication of the present issue, nor do we want to delay further a number of reviews of books and other publications that may interest our readers. Hence we will include such items as are ready in the present short number.

Rather than including extensive bibliographic material in Island News and Comment, we hope in the future to devote an entire issue to bibliographic articles noting and commenting on island literature. We are, hence, very much interested in receiving reprints and other papers dealing with islands, as well as references to such works if copies are not available.

We also welcome informative or critical reviews of significant books or other publications on islands or reefs. If they are typed in the format used for reviews in this issue the editors' work will be facilitated.

NEWS

THIRD INTERNATIONAL CORAL REEF SYMPOSIUM: Under joint sponorship of the University of Miami, the U.S. Geological Survey, and the Smithsonian Institution, a third of the series of symposia started at Mandapam Camp, India and continued on the S.S. Marco Polo on the Great Barrier Reef, Australia, will be held at the University of Miami, in Miami, Florida, May 23 - 27, 1977, with a reception to be held on the evening of May 22. The second circular, being mailed as this is written, will give authoritative details.

Before and after the symposium, field trips are being planned and with leaders as follows:

Jamaica	Jeremy Woodley
Barbados	Noel James & Colin Stearn
Bermuda	Wolfgang Sterrer
Bahamas	Conrad Gebelein
Grand Cayman	Harry Roberts & Clyde Moore
Belize	James Miller & Ian Macintyre
Martinique & St. Croix	Walter Adey & Robert Dill
Panama	Ross Robertson & Peter Glynn
Florida Keys & Florida Bay	Gene Shinn
Dry Tortugas	Gary Davis

231-339 O - '77 - 17

Whether or not any particular one of these trips will take place will depend on whether sufficient people indicate that they will participate. The trips must be self-supporting, as there is no available source of funds to subsidize them.

The chairman of the organizing committee is:

Dr. R. N. Ginsburg
Fisher Island Station
Miami Beach, Fla. 33139

MID-PACIFIC MARINE LABORATORY: The U.S. Energy Research and Development Administration (Division of Biomedical and Environmental Research) supports the operation of the Mid-Pacific Marine Laboratory on Enewetak Atoll as an extension of the Hawaii Institute of Marine Biology (University of Hawaii). The laboratory has recently been reorganized and expanded to a year-round operation, with special interest in programs related to the distribution of radionuclides and other materials in an atoll environment, the cycling of these materials through the atoll ecosystem, and the possible implications of these processes to man. Researchers interested in undertaking studies at Enewetak should contact Dr. Stephen V. Smith, Director, MPML, P. O. Box 1346, Kaneohe, Hawaii, 96744.

FILM AVAILABLE ON THE ECOLOGY AND ETHOLOGY OF CORAL REEF FISHES: Dr. Ernst S. Reese, Department of Zoology and the Hawaii Institute of Marine Biology of the University of Hawaii, has completed an educational documentary film on the social behavior and related aspects of ecology of butterflyfishes of the Family Chaetodontidae. This is a professional quality film in color, 16mm with sound. The film was made over the past 8 years during studies carried out in Hawaii, at Eniwetok Atoll in the Marshall Islands, and at Heron Island on the Great Barrier Reef. The film shows the feeding and agonistic behavior of 15 species. Each species belongs to one of three feeding "guilds" (coral feeders, omnivores, plankton feeders) which in turn determines the space-related behavior of each species. The purpose of the film was to examine how one group of fishes successfully coexists and shares the resouces of space and food on the reef. There is an intimate relationship between the patterns of social behavior and the ecology of each species which has resulted in the different strategies of resource utilization. A detailed study guide is available with the film. For a brochure and further information on rental, preview or purchase, please write to Dr. Ernst S. Reese, Hawaii Institute of Marine Biology, P.O. Box 1346, Kaneohe, Hawaii 96744.

SECOND SMITHSONIAN PHOENIX ISLAND EXPEDITION: As a follow-up to their 1973 expedition to the Phoenix Islands, Roger Clapp, F. R. Fosberg, and D. R. Stoddart revisited the Phoenix Islands in March and April, 1975, courtesy of the SAMTEC Project of the U.S. Air Force. The official purpose of the visit was to assess the environmental effects of Air Force activities on Enderbury and Hull Islands. Scientific observations were made in various fields and a series of topographic profiles were levelled across various transects of the islets. Fortunately it was possible to

visit all eight of the atolls, so the reconnaissance study of the Phoenix Group was essentially completed. Reports on several aspects are being prepared for publication in a future issue of ARB.

COMMENT

THE PROBLEM OF DEFINITION OF THE TERM "ATOLL": I was recently asked about definitions of atolls and especially about what to call Cayo Sal, of the Venezuelan coast. This is a somewhat edited version of my reply, which may be of interest to some readers.

This raises a question of terminology which probably never can be resolved except arbitrarily, and then certainly not to the satisfaction of all groups of users. The difficulty is that different groups tend to write definitions to satisfy different requirements and it is often not possible to formulate a definition that suits all purposes equally well.

For geologists the essential characteristics seem to be that the material must be reef limestone or at least calcareous skeletal debris and that the reefs and islets must surround or partially surround a shallow body of water termed a lagoon. Some geologists insist that the structure rise from deep water, others are willing to accept an essentially morphological definition, though they argue endlessly about the origin of the essential form.

The definition quoted to you by Dr. Bryan was formulated by ecologists, essentially for use by ecologists. It differs from other definitions in that it also includes islands which do not have lagoons but are emergent though essentially sea-level reef-limestone structures. It excludes those that are elevated more than a very few meters above mean low-tide level, and it also excludes such islands as are closely associated with high islands or continental land, or are separated from such higher land only by shallow water.. Bryan has used the 100 fathom line as separating shallow from deep water. I would probably use a shallower limit, such as 100 m. However, this illustrates one of the principal problems with definitions of natural phenomena. They usually do not exhibit sharp boundaries and tend to be continua, with gentle to sharp gradients. There seems to be no easy solution to this problem. The only one that at all satisfies me is to make the definition apply to the main body or "core" of the phenomenon and be arbitrary about just where in the transitional area the boundary should be recognized.

I realize that this will not satisfy anyone who simply wants an authoritative definition. Some years ago we had a project to compile an "Oxford Dictionary" type glossary of coral reef terms. Several of us participated in the work, with Prof. Rhodes W. Fairbridge as editor. It was never published. Now the manuscript is being updated by a committee on terminology set up at the Second International Coral Reef Symposium in 1973, under chairmanship of David R. Stoddart. Hopefully this will see the light of day sometime soon. However, it will merely bring out the true demensions of the problem, but will not solve it.

Really, the only thing I can suggest is that you either use the term atoll and define it to your satisfaction, or, alternatively, dodge the question by calling Cayo Sal an "atoll-like island."

F. R. Fosberg

AN IRRESPONSIBLE SCIENTIFIC EXPEDITION: From August 22 to October 21 an expedition, called Line Islands Expedition, mounted by the Gilbert and Ellice Islands Government which toured the islands in the central Pacific which are or will possibly become part of the new independent Gilbert and Ellice Islands nation. The purpose was to assess the economic possibilities of the islands and to collect scientific information that may be of use in administering these islands by the new government. The personnel of the expedition were officials of the government and, in addition, an ornithologist from Hamburg, Germany and a graduate student from Hawaii interested in corals.

The islands visited were Christmas, Fanning, Washington, Malden, Starbuck, Caroline, Flint, Vostok, Phoenix, Sydney, Hull, and Gardner. Reports were submitted to the government by the principal members of the expedition, either general, or on the specific subjects covered by certain members, which were duplicated but appear to be unedited. Their scientific content will not be commented on here. Perhaps it will appear later in a more finished state.

What is of immediate interest is information in several of these reports on the unfortunate behavior of crew members of the ship Teraaka, during their visits to the islands. What transpired was apparently an orgy of slaughter of all sea-birds that they could lay hands on--nesting birds that trustingly do not leave their nests at the approach of man. In some instances almost whole populations were killed, to some extent for food, but mostly just for "sport".

Furthermore, while some of these birds were being cooked, the thick dry "peat" under the Pisonia forest on Vostok Island was set on fire. An attempt was made to put out the fire, but it was evidently not completely extinguised, and was recently reported as still burning. Vostok is, or was, a perfect gem of an island unaltered by man. It was a perfect, functioning relatively simple natural ecosystem, a notable sea-bird rookery, a natural laboratory for the study of phosphate rock formation processes and other biological interactions and environmental relations. It was a prime candidate for preservation as an internationally recognized "island for science." Now, if the report of the persistence of the fire is true, it will be reduced to a barren and lifeless waste, a desert island in the worst sense of the term.

If this is an example of the way the citizens of the new nation behave, right under the eyes of their government officials, the future of any of the non-human inhabitants of these central Pacific islands looks dim indeed. And if the biota and the total biological diversity of these island ecosystems become progressively more and more depleted, the long-term future of the islanders also looks very dim.

We regard it as a shame that such occurrences took place on a scientific expedition. We concur fully with the recommendations of Dr. Grossmann, the expedition ornithologist, on pages 16-18 of his report, as minimum steps to be taken. We agree that education in conservation principles in the schools is the only long-term effective solution to such problems. It is obvious that the education of the present generation of adults has been woefully deficient in these matters.

REVIEWS:

Carlquist, S. 1974. Island Biology. 1-660, Columbia University Press, N. Y. and London, $25.00. No one seriously interested in the scientific aspects of islands can very well afford not to have this book immediately available. Not only are few aspects of island biology neglected, but there are few where significant new information and ideas are not presented. A new starting point is provided for the study of many important aspects of this subject. Although there may be many areas where others will differ from the views expressed by Carlquist, one cannot afford to neglect to examine his data, ideas, and conclusions critically.

He has been fortunate to have opportunities to amass a vast amount of actual experience and data on islands and island-like areas throughout the world. Where he has known of or suspected interesting insular phenomena he has gone. His institution, Claremont Graduate School, is to be congratulated on giving him the freedom to do this, as is his mother for making his early insular explorations possible.

To avoid an encyclopedia-sized work, he has adopted the approach of only mentioning, not repeating, the detail given already in his own extensive publications and in readily available works of others. He has not, of course, omitted points necessary to support the ideas expressed here, but has as nearly as practical made this a work presenting his own newly discovered or recorded data and the new ideas and conclusions to which they have led him. Although casting a wide net for important facts and ideas in the works of others, and giving full credit for these, this is essentially his own work and seems fully internally coherent and consistant--amazing for a 660 page book.

Logically the first chapter deals with dispersal--how the ancestors of island species may have reached the islands. This is a vexed subject on which there has been much speculation based mostly on purely circumstantial evidence. Carlquist's chapter is no exception to this. It is perhaps the weakest chapter in the book. It ascribes great effectiveness to bird transport, on the basis of fleshiness of fruit and such features, and admits little importance for wind. Familiarity with typhoon-strength winds and knowledge of "jet streams" suggests to me that wind may be a very important agent even for dispersal of plants that are obviously specially equipped to be carried around locally by birds or other agencies. Long distance dispersal must, under any circumstances, be an extremely infrequent and unusual event. This is perhaps not sufficiently stressed in the chapter on dispersal, which in most respects is very thorough.

One of the features of island evolution that has been most discussed, and that Carlquist devotes seven chapters to, is the so-called "adaptive radiation." This is the phenomenon of differentiation of populations of a group to enable them to occupy a diversity of habitats or ecological niches, developing distinctive adaptive features and behavior patterns accordingly. The first of the seven chapters on this subject, discusses in detail the general features and implications of the concept, and is certainly the most adequate and thought-provoking treatment of the subject that I have seen. In particular, it offers an explanation of why adaptive radiation seems so conspicuously a feature of oceanic island biotas. This he relates to the "disharmonic" nature of these biotas, the incomplete and unbalanced representation of the broad spectrum of families normally found in continental areas. Thus lessened competition, or evolutionary vacua, permit expression of evolutionary potentials in a particular group that would be prevented by prior effective occupancy of most of the niches by members of other groups. This principle, while implicit in some previous discussions of adaptive radiation, is here brought out with admirable clarity and with abundant illustrative examples and detail. It is a major accomplishment of the book. The other six chapters on the subject are detailed expositions of the occurrence of adaptive radiation in the principal geographical regions where it is conspicuous.

The following chapters are, with one exception, devoted to classes of features prominent in island biotas that are not, or at least not obviously, the result of adaptive radiation or clear responses to habitat factors. These include woodiness in usually herbaceous plant groups; gigantism; types of loss of, or reduced, dispersability such as flightlessness, reduction of obvious dispersal mechanisms, increase in size of propagules, and other less striking but possibly equally pertinent phenomena; peculiar developments in reproductive biology; reduction, modification or loss of appendages in animals; and other topics related to or correlated with insularity.

Chapter 15 is a lengthy essay on equatorial highlands and mountains showing how they partake of the nature of islands, sharing some of the features discussed earlier in the book for true islands. An impressive amount of information is brought together under this head. In this, as here and there in previous chapters, one occasionally gets an impression of strained interpretations, but these are sometimes most thought-provoking.

Although the coverage of the whole subject of insular phenomena is by far the most thorough ever written, it is done in such a fashion as to be challenging. Further work and discussion are provoked and stimulated rather than cut off. A tremendous field, full of problems, is laid out. Reference to previous documentation is extensive. Each chapter has a large list of cited references. The material in the whole work is made readily accessible by an index of biological names used and by a remarkably detailed subject index.

Lest the above generally laudatory comments lull uncritical readers into accepting everything in the book as gospel, a few particular points

may be indicated where erroneous statements have crept in or where there is room for strong difference of opinion: Page 8, the Tahitian cotton is not endemic, even though it has been called Gossypium taitense. P. 11, the last two sentences seem to be somewhat contradicted by the discussion of geckos in the last paragraph on p. 8. Pp. 31 and 38, the date of the Fosberg Gouldia reference should be 1936. P. 63, Peperomia does not have "relatively large seeds." P. 70, rather than Boerhavia diffusa the Pacific Island Boerhavia is mostly B. repens, which is notably polymorphic species. The suggestion that pantropical strand species lack variation only indicates that slight attention has been paid to them, probably because of the widespread idea that they lack variation. P. 80, Oeno Atoll is not a raised atoll. P. 86, Rhipsalis definitely shows differentiation, at least in Madagascar. P. 131, the expression "most mesic" suggests that mesic is synonymous with wet, rather than intermediate between xeric (dry) and hydric (wet). Pp. 212-213, the statement that geological sequences of islands from old to young are not present in southern Polynesia is definitely erroneous, as such sequences are very clear in the Society, Cook and Austral island groups. P. 359, there are many lowland arborescent plants in the Galapagos, at least, that are not stem-succulents, e.g. Croton, Bursera, Acacia, Pisonia. P. 450, an exception to the statement that Pacific Bidens have not advanced far toward arborescence is B. hendersonensis which is truly a small tree, some meters tall and with a strong, hard woody trunk. P. 480, contrary to the statement that neither fruits nor seeds of Sapindus are known to be capable of flotation, seeds of Sapindus saponaria are not uncommon in tropical beach drift. P. 483, Pleomele, a weak segregate from Dracaena, is definitely not an endemic Hawaiian genus, but includes species in other areas.

The book is generally attractively put together, with abundant illustrations, as well as excellent drawings. Many of the author's well-known superb photographs are included, but the quality of the reproduction of many of them is disappointing. The captions of plates 14.14, 14.15, and 14.17 are transposed. The lines are rather long for comfortable reading.

In spite of such minor criticisms, Island Biology is a tremendous achievement and establishes Carlquist as probably the greatest name in the contemporary island biological field.

F. R. Fosberg

Wood, E. J. F. and R. E. Johannes. Tropical Marine Pollution. 192 pp. Elsevier Oceanography Series 12, Elsevier, Amsterdam, Oxford, N. Y. 1975. $26.95. It is not often that a review of a major subject can come close to covering all that is known about the subject. That the editors of this book could not only succeed in doing this, but include one major original research report, is an indication of how meager our knowledge of tropical marine pollution is. The paucity of information, however, is not an indication that the subject is unimportant. Enormous populations in tropical countries and on tropical islands live in immediate proximity to the sea and are dependent on it for part of their nutrition. The biota of the tropical oceans are enormous and diverse. The growing threat of death from man-caused pollution hangs over all tropical marine and maritime plants and animals, including man.

Why tropical marine pollution? Johannes, in his introductory chapter, deals with this question and shows clearly that knowledge derived from temperate situations cannot necessarily be extrapolated to tropical ones. Tropical organisms are usually living much nearer their lethal temperature threshold than are those in temperate waters, and that other physiological tolerances are also narrower in the tropics. He shows in tabular form a long list of comparisons of pertinent features of tropical organisms with corresponding temperate ones.

The other chapters in the book are:

Chapter 1. INTRODUCTION: MARINE COMMUNITIES RESPOND DIFFERENTLY TO POLLUTION IN THE TROPICS THAN AT HIGHER LATITUDES (R. E. Johannes and Susan B. Betzer)

Chapter 2. POLLUTION AND DEGRADATION OF CORAL REEF COMMUNITIES (R. E. Johannes)

Chapter 3. THE RESPONSE OF MANGROVES TO MAN-INDUCED ENVIRONMENTAL STRESS (William E. Odum and R. E. Johannes)

Chapter 4. TROPICAL SEA GRASS ECOSYSTEMS AND POLLUTION (J. C. Zieman)

Chapter 5. EFFECTS OF THERMAL POLLUTION ON TROPICAL-TYPE ESTUARIES, WITH EMPHASIS ON BISCAYNE BAY, FLORIDA (J. C. Zieman and E. J. Ferguson Wood)

Chapter 6. BIOLOGICAL IMPACT OF A LARGE-SCALE DESALINATION PLANT AT KEY WEST, FLORIDA (Richard H. Chesher)

From our viewpoint Johannes' own masterful treatment of the impact of pollution on coral reefs is the core of the book. Probably no one would have been nearly as capable of writing this account as Bob Johannes. Anyone concerned with the future of coral reefs will find it of great interest.

The chapters on mangroves, by Odum and Johannes and on sea-grass ecosystems by Zieman will also be of concern to many of our readers.

Suffice it to say that the tropical marine ecosystems are already in trouble, and that the trouble will surely get worse as long as the sea is used as the world's cesspool.

I have only one criticism of the editing that is worth mentioning. The habit of abbreviating generic names in binomials is a great nuisance and source of confusion when the full binomial has not been spelled out at least on the same page, preferably in the same paragraph. It is particularly bad when several generic names are abbreviated which begin with the same initial letter.

The book is expensive, but is essential to any tropical marine biologist. It has also the virtue of being readable (except parts of Chesher's chapter) and interesting.

F. R. Fosberg

Johannes, R. E., et al. The metabolism of some coral reef communities; a team study of nutrient and energy flux at Eniwetok. BioScience 22(9): 541-543. 1972. The high biological productivity of atoll coral reefs bathed by nutrient-poor oceanic waters has been long appreciated but poorly understood. This preliminary report heralds some of the interesting results from a formidable team effort to illumine some of the processes that maintain a coral reef ecosystem.

From their base aboard the research vessel Alpha Helix of the Scripps Institute of Oceanography in May-June, 1971, a team of scientists was able to simultaneously monitor a large variety of changes in chemical, biological and physical properties of sea water flowing over the windward reef at Eniwetok Atoll near the old transect laid out by Odum and Odum in their pioneering reef ecosystem study (Ecol. Monogr. 24: 291-320, 1955).

Nitrogen fixation proceeds at very high rates in the system, resulting in a net export of that element from the reef. N fixation in turn is allied to efficient utilization of phosphorus, very little of which is lost from the benthic reef community to the water. Phosphorus, it is suggested, must be recycled very efficiently between photosynthetic organisms and heterotrophic ones. In this context it is interesting that the presence of endozoic algae in the tissue of corals and other reef organisms is directly correlated with low release of dissolved organic and inorganic phosphorus.

Bryce Decker

King, Warren B., ed. Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool. 158: 1-277. 1974. Those who have seen the concentrations of seabirds in island rookeries during breeding seasons and their almost total absence on the same islands during other parts of the year can scarcely help wondering where they go. For some species this information has been very scanty, indeed, in the past. The Pacific Ocean Biological Survey Program of the Smithsonian provided excellent opportunities to work on this problem, and this publication is a beginning toward making the results of these observations available. It includes seven papers treating the Sooty Fern, the Wedge-tailed Sheawater, the Black-footed and Laysan Albatrosses, 18 species of Storm Petrels, and the Red-tailed Tropic Bird in detail. The papers are abundantly illustrated with maps, diagrams and tables, and the volume contains a short, by no means exhaustive, list of pertinent references to previous work. Those interested will await the future numbers of the series that will treat other bird species.

F. R. Fosberg

McGregor, C. The Great Barrier Reef. Time-Life Books, Amsterdam, 1-184. 1974. This is a beautifully illustrated account of one of the most remarkable and magnificent features on the face of the earth. It can be highly recommended to the non-technical person who has an intelligent interest in the unusual features of the world and an appreciation for outstanding natural beauty. The author emphasizes the fact that even a 1260 mile-long complex of reefs, channels, lagoons, and island is threatened with exploitation and degradation at the hands of man in this greedy age.

F. R. Fosberg

TANE vols. 17: 1-212, 1971; 18: 1-200, 1972. This handsome little journal is published by the Auckland University Field Club, and carries articles on New Zealand natural history, with much material on the off-shore islands around New Zealand. It is especially dedicated, though not restricted, to the publication of articles written by students, reporting their own original field studies and observations. Within this framework the articles maintain a very high standard and are both well written and well edited. The content runs the gamut of outdoor observational natural history, including archaeology.

These two recently received volumes are of special interest in that each reports the results of a student-organized expedition, or annual field camp, to a small island. Vol. 17 contains 8 articles resulting from the 1970 Whale Island field camp, as well as articles on other small islands and several on mainland observations. Vol. 18 is largely taken up by 15 articles resulting from the 1971 Red Mercury Island field camp.

One cannot commend too highly this type of training in field biology. It at the same time introduces beginning biologists to serious scientific study, with results valuable to science, and provides them an incentive to maintain a quality in their observations high enough to stand the scrutiny of their scientific colleagues normally directed to published

work. The results, as shown by these articles, are very worth-while.

The subscription price of TANE is at present $1.00 per volume. Correspondence should be addressed to:

TANE
c/o The Botany Department
University of Auckland
Private Bag, Auckland, N. Z.

F. R. Fosberg

SHORT ARTICLE

Remarks on the Botany and Statistics of the Bahama Islands

by William T. Gillis

NATURAL HISTORY OF THE BAHAMA ISLANDS

The Bahama Islands consists of nearly 30 major islands, 661 smaller ones called cays (pronounced "keys"), and nearly 2400 rocks, jutting over a shallow platform with ocean deeps surrounding it. The total area is over 4,400 square miles. The islands stretch in a giant arc 760 miles long from northwest to southeast, with greatest width about 150 miles (from Gun Cay to Man-of-War Cay, Abaco). The archipelago straddles the Tropic of Cancer with Georgetown, Great Exuma lying just a few miles north of this line. The span is from 20° 55' to 27° 30' N. Lat. and from 71° 10' to 79° 20' W. Long. which places the islands in the trade wind belt.

Topography is somewhat monotonous, the highest point on any of the islands being Mt. Elvernia on Cat Island with an elevation of 210 feet. Much of the island group (e.g., the western side of Andros, the southern half of Middle Caicos, etc.) is known as "swash" and is subject to overflow by the sea in very high tides and in storms. Large salt-water lakes at sea level occur on several islands, there appearing to be no connection with the sea except likely underground. There are only two so-called rivers in the whole archipelago, both on Andros. Other seemingly freshwater lakes are high in calcium ion concentration.

The Bahamas enjoy a climate of the tropical savanna type (Aw in the Köppen system), with no frost ever recorded. Rainfall decreases southward from about 50-60 inches in the north to less than 20 inches in Inagua. Hurricanes are likely to strike some part of the islands every few years. Because of the limestone substrate's presence close to the surface, only about 35,000 acres of land are presently under cultivation. A dairy herd is maintained on Eleuthera. An abandoned sugar mill stands on Abaco. Native pine has been harvested on the northern islands but not touched commercially in the disjunct area in the Caicos group (it has been bulldozed there however).

The flora consists of about 1000 species of vascular plants, about 30 of which are endemic. The vegetation types appear to be fairly simple, consisting mainly of pineland, coppices (not unlike the hammocks of southern Florida), scrublands of shrubs and small trees (called simply "bush" in the islands), strands and mangroves. The floristic relationships of the flora and vegetation are generally with Florida, Cuba, Hispaniola, and to a lesser extent, Puerto Rico and Yucatan.

[Supporting papers for a talk given at the annual meeting of the Association for Tropical Biology at the Smithsonian Institution, December 1974, that we thought might interest some of our readers.--Eds.]

There are two political units within the geographical region called the Bahamas: the Commonwealth of the Bahamas (which received independence within the British Commonwealth on 10 July 1973), and the Turks and Caicos Islands, a Crown Colony of Great Britain. Prior to Jamaican independence, the Turks and Caicos were administered as part of Jamaica. Since 1848, they have not been affiliated with the Bahama Islands politically. From April 1972 until a few months ago, there were no commercial transportation connections between these two political units!

(prepared December 1974)

PHYTOGEOGRAPHIC HYPOTHESES RELATING TO BAHAMA FLORA

1. All plants of the Bahamas have had a source area outside the Bahamas. For endemics, the progenitors were from outside the region, and are probably missing from the region now.

2. Bahama plants which are also in Florida are chiefly restricted to the Florida Keys, or at least south of Lake Okeechobee. A few species have entered the Bahamas from Florida. These are restricted to the northern islands (e.g. Asters, poison ivy).

3. Plants which do not cross the Gulf Stream from the Bahamas into Florida by and large have no special adaptation for wind dispersal, nor are eaten by birds, nor have any special niche in South Florida.

4. Most new plants in the flora (that is, have entered the region in recent years) have probably been introduced by wind (especially hurricanes), by rafting, or by birds. Some inadvertent introduction by activities of man is probably also at work.

5. Endemism increases with the size of islands (banks), lessening of rainfall, and decreasing latitude.

6. San Salvador has a greater affinity with Hispaniola in its fauna and flora than can be explained by proximity.

7. Each island has a distinctive assemblage of plants, with different dominants on each island. Exception: Abaco and Grand Bahama.

8. Toward the south, the following trends are noted:

    Strand plants of the north move into upland thickets.

    Species develop broader leaves.

    More species occur that have gray, dead-looking foliage.

    There is a tendency for the plants present to be more drought-resistant.

9. Anomalous situations:

Why is Grand Turk's flora so similar to that of South Caicos?

What is the cause of the present distribution of pine?

What prevents the Cuban element in the flora of South Andros from crossing into Mangrove Cay or North Andros?

Why does the "southern element" in the flora not move up the Exuma Cays to New Providence?

(Prepared 1974)

PLANT DISTRIBUTION IN THE BAHAMA ISLANDS

Cosmopolitan species - mangroves
strand plants

Bahamas - Cuba

South Andros - Cuba - Catalpa punctata
Pseudocarpidium wrightii
Callicarpa hitchcockii
Phoradendron trinervium
Crossopetalum aquifolium

Bahamas - Yucatun - Mimosa bahamensis

Bahamas - Hispaniola

San Salvador - Hispaniola - Croton discolor
Zanthoxylum bifoliolatum

Aberrant - Chamaesyce vaginulata
Limonium bahamense
Nashia inaguense
Caesalpinia murifructa

Bahamas - Florida

(a) widespread in Florida
(b) southern tip of peninsula or Florida Keys

Plants on Bimini and/or Grand Bahama and not in Florida:

Thouinia discolor
Diospyros crassinervis
Tabebuia bahamensis
Phialanthus myrtilloides
Triopteris jamaicensis
Stigmaphyllon sagraeanum
Grimmeodendron eglandulosum

Haematoxylum campechianum
Rhachicallis americana

Cassia lineata
Buxus bahamensis
Erythroxylum spp.

Endemic - 2 species of Agave (Section Bahamana)
1 species of Vernonia
1 species of Marsilea
1 species of Lobelia
1 species of Cynanchum

Cuba - Cay Sal - Chamaesyce centunculoides

APPROXIMATE SIZES OF THE MAJOR ISLANDS

	Dimensions	Square Miles
Abaco	105 X 7 miles	372
Acklins	37 X 4 miles	192
Andros	111 X 22 miles	2,300
Berry Islands		12
Bimini		8.5
Cat	43 X 3 miles	150
Crooked	19 X 4 miles	70
Eleuthera	90 X 3 miles	200
Exuma	40 X 3 miles	61
Exuma Cays and Little Exuma		51
Grand Bahama	73 X 7 miles	530
Inagua (incl. Little Inagua)	40 X 14 miles	600
Long	64 X 4 miles	230
Mayaguana	26 X 5 miles	110
New Providence	21 X 7 miles	80
Ragged		5
Rum Cay	11 X 5 miles	30
San Salvador	15 X 5 miles	60
Cay Sal and Lobos		2

(Lands and Surveys Dept., Ministry of Development, Commonwealth of the Bahamas, Statistical Abstract, 1970).

POPULATION OF THE BAHAMAS

Abaco	6,501
Acklins	936
Andros	8,845
Berry Islands	443
Bimini (and Cay Lobos)	1,503
Cat	2,657
Crooked	689
Eleuthera	9,468
Exuma	3,767
Grand Bahama	25,859
Harbour Island and Spanish Wells	3,227*
Inagua	1,109
Long Cay (Fortune)	26
Long Island	3,861
Mayaguana	581
New Providence	101,503
Ragged	208
Rum Cay	80
San Salvador	776
TOTAL	168,812 (1970 Census)

(Dept. of Statistics, Cabinet Office, Commonwealth of the Bahamas, Statistical Abstract, 1970)

---

* The population of these islands is also included in the figure for Eleuthera. The grand total does not count this figure twice.

List of Atoll Research Bulletin
titles issued to date

To avoid the correspondence resulting from numerous requests for titles of all ARB numbers issued to date we are listing them here. We also take this opportunity to inform those interested that numbers 1-117 are entirely exhausted or almost so. A few copies of some of them are left but will only be sent to fill gaps in sets in libraries of institutions actively engaged in research on islands. A $10 per number charge plus a $5 issue handling charge will be assessed for supplying these, the money to be paid into the Smithsonian Institution ARB fund.

1. Basic information papers, by various authors. 1-25, Sept. 10, 1951.

2. Symposium on coral atoll research, by various authors. 1-14, Sept. 10, 1951.

3. Vertebrate ecology of Arno Atoll, Marshall Islands, by J. T. Marshall, Jr. 1-38, Oct. 15, 1951.

4. Marine zoology study of Arno Atoll, Marshall Islands, by R. W. Hiatt and D. Strasburg. 1-13, Oct. 15, 1951.

5. The soils of Arno Atoll, Marshall Islands, by E. L. Stone, Jr. 1-56, Nov. 15, 1951.

6. The agriculture of Arno Atoll, Marshall Islands, by E. L. Stone, Jr. 1-46, Nov. 15, 1951.

7. The plants of Arno Atoll, Marshall Islands, by D. Anderson. 1-4, i-vii, Nov. 15, 1951.

8. The hydrology of Arno Atoll, Marshall Islands, by D. C. Cox. 1-29, Dec. 15, 1951.

9. The coral reefs of Arno Atoll, Marshall Islands, by J. W. Wells. 1-14, Dec. 15, 1951.

10. Anthropology-geography study of Arno Atoll, Marshall Islands, by L. Mason, J. Tobin and G. Wade. 1-21, Sept. 1, 1952.

11. Land tenure in the Marshall Islands, by J. Tobin. 1-36, Sept. 1, 1952.

12. Preliminary report on geology and marine environment of Onotoa Atoll, Gilbert Islands, by P. E. Cloud, Jr. 1-73, Dec. 15, 1952.

13. Preliminary report on marine biology study of Onotoa Atoll, Gilbert Islands, by A. H. Banner and J. E. Randall. 1-62, Dec. 15, 1952.

14. Description of Kayangel Atoll, Palau Islands, by J. L. Gressitt. 1-6, Dec. 15, 1952.

231-339 O - '77 - 18

15. The insect life of Arno, by R. L. Usinger and I. La Rivers. 1-28, April 30, 1953.

16. The land vegetation of Arno Atoll, Marshall Islands, by W. H. Hatheway. 1-68, April 30, 1953.

17. Handbook for atoll research, by various authors, edited by F. R. Fosberg and Marie-Hélène Sachet. 1-129, Mary 15, 1953.

18. Ichtyological field data of Raroia Atoll, Tuamotu Archipelago, by R. R. Harry. 1-190, July 31, 1953.

19. Check list of atolls, by E. H. Bryan, Jr. 1-38, Sept. 30, 1953.

20. Health report of Kapingamarangi, by R. E. Miller, 1-42, Sept. 30, 1953.

21. Notes on Ngaruangl and Kayangel Atolls, Palau Islands, by J. L. Gressitt. 1-5, Sept. 30, 1953.

22. Summary of information atoll soils, by E. L. Stone, Jr. 1-4, Sept. 30, 1953.

23. Vegetation of Central Pacific Atolls, a brief summary, by F. R. Fosberg. 1-26, Sept. 30, 1953.

24. Enumeration of the decapod and stomatopod Crustacea from Pacific coral islands, by L. B. Holthuis. 1-66, Nov. 15, 1953.

25. Bryophytes from Arno Atoll, Marshall Islands, by H. A. Miller and M. S. Doty. 1-10, Nov. 15, 1953.

26. Scorpions on coral atolls, by M.-H. Sachet. 1-10, Nov. 15, 1953.

27. Nutrition study in Micronesia, by M. Murai. 1-239, Jan. 31, 1954.

28. Preliminary report on land animals at Onotoa Atoll, Gilbert Islands, by E. T. Moul. 1-28, May 31, 1954.

29. A summary of information on Rose Atoll, by M.-H. Sachet. 1-25, May 31, 1954.

30. The hydrology of the Northern Marshall Islands, by T. Arnow. 1-7, May 31, 1954.

31. Expedition to Raroia, Tuamotus, Part 1. Expedition to Raroia, Tuamotus, by N. D. Newell. 1-12; Part 2. Physical characteristics of Raroia, by N. D. Newell. 13-21; Part 3. General map of Raroia Atoll, by N. D. Newell. Nov. 30, 1954.

32. Raroian Culture, Part 1. Economy of Raroia Atoll, Tuamotu Archipelago, by B. Danielsson. 1-91; Part 2. Native topographical terms in Raroia,

Tuamotus, by B. Danielsson. 92-96; Part 3. Native terminology of the coconut palm in Raroia Atoll, by B. Danielsson. 97-99; Part 4. Bird names in Raroia Atoll, by B. Danielsson and A. Natua. 100-101; Part 5. Check list of the native names of fishes of Raroia Atoll, by B. Danielsson. 102-109, Nov. 30, 1954.

33. Floristics and plant ecology of Raroia Atoll, Tuamotus, Part 1. Floristic and ecological notes on Raroia, by M. S. Doty. 1-41; Part 2. Ecological and floristic notes on the Myxophyta of Raroia, by J. Newhouse. 42-54; Part 3. Ecological and floristic notes on the Bryophyta of Raroia, by H. A. Miller and M. S. Doty. 55-56; Part 4. Ecological and floristic notes on the Pteridophyta of Raroia, by K. Wilson. 57-58, Nov. 30, 1954.

34. Animal ecology of Raroia Atoll, Tuamotus, Part 1. Ecological notes on the mollusks and other animals of Raroia, by J. P. E. Morrison. 1-18; Part 2. Notes on the birds of Raroia, by J. P. E. Morrison, 19-26, Nov. 30, 1954.

35. Interrelationship of the organisms on Raroia aside from man, by M. S. Doty and J. P. E. Morrison. 1-61, Nov. 30, 1954.

36. Reefs and sedimentary processes of Raroia, by N. D. Newell. 1-35, Nov. 30, 1954.

37. Pumice and other extraneous volcanic materials on coral atolls, by M.-H. Sachet. 1-27, May 15, 1955.

38. Northern Marshall Islands Expedition, 1951-1952. Narrative by F. R. Fosberg. 1-36, May 15, 1955.

39. Northern Marshall Islands Expedition, 1951-1952. Land biota: Vascular plants, by F. R. Fosberg. 1-22, May 15, 1955.

40. Bryophytes collected by F. R. Fosberg in the Marshall Islands, by H. A. Miller. 1-4, May 15, 1955.

41. Canton Island, South Pacific, by O. Degener and E. Gillaspy. 1-51, Aug. 15, 1955.

42. The insects and certain other arthropods of Canton Island, by R. H. Van Zwaluwenburg. 1-11, Aug. 15, 1955.

43. The natural vegetation of Canton Island, an equatorial Pacific atoll, by W. H. Hatheway. 1-9, Aug. 15, 1955.

44. The hydrology of Ifalik Atoll, Western Caroline Islands, by T. Arnow. 1-15, Aug. 15, 1955.

45. A partial list of the plants of the Midway Islands by J. A. Neff and P. A. DuMont. 1-11, Aug. 15, 1955.

46. Conspicuous features of organic reefs, by J. I. Tracey, Jr., P. E. Cloud, Jr. and K. O. Emery. 1-3, Aug. 15, 1955.

47. Fishes of the Gilbert Islands, by J. E. Randall. 1-243, Aug. 15, 1955.

48. The geography of Kapingamarangi Atoll in the Eastern Carolines, by Herold J. Wiens. 1-86, 1- [7], June 30, 1956.

49. Bioecology of Kapingamarangi Atoll, Caroline Islands: Terrestrial aspects, by William A. Niering. 1-32, June 30, 1956.

50. Geology of Kapingamarangi Atoll, Caroline Islands, by Edwin D. McKee. 1-38, June 30, 1956.

51. Observations on French Frigate Shoals, February 1956, by Arthur Svihla. 1-2, Sept. 15, 1957.

52. Zonation of corals on Japtan Reef, Eniwetok Atoll, by Eugene P. Odum and Howard T. Odum. 1-3, Sept. 15, 1957.

53. Slicks on ocean surface downwind from coral reefs, by F. R. Fosberg. 1-4, Sept. 15, 1957.

54. Field notes on atolls visited in the Marshalls, 1956, by Herold J. Wiens. 1-23, Sept. 15, 1957.

55. Agricultural notes on the Southern Marshall Islands, 1952, by W. H. Hatheway. 1-9, Sept. 15, 1957.

56. Atolls visited during the first year of the Pacific Islands Rat Ecology Project, by J. T. Marshall, Jr. 1-11, Sept. 15, 1957.

57. Preliminary report on the flora of Onotoa Atoll, Gilbert Islands, by Edwin T. Moul. 1-48, Sept. 15, 1957.

58. The Maldive Islands, Indian Ocean, by F. R. Fosberg. 1-37, Sept. 15, 1957.

59. Report on the Gilbert Islands: Some aspects of human ecology, by René L. A. Catala. 1-187, Oct. 31, 1957.

60. Climate and Meteorology of the Gilbert Islands, by M.-H. Sachet. 1-4, Oct. 31, 1957.

61. Long-term effects of radioactive fallout on plants? by F. R. Fosberg. 1-11, May 15, 1959.

62. Health and sanitation survey of Arno Atoll, by J. D. Milhurn. 1-7, May 15, 1959.

63. Report on a visit to the Chesterfield Islands, September, 1957, by by F. Cohic. 1-11, May 15, 1959.

64. Canton Island, South Pacific (Resurvey of 1958), by Otto Degener and Isa Degener. 1-24, May 15, 1959.

65. Some marine algae from Canton Atoll, by E. Yale Dawson. 1-6, May 15, 1959.

66. Notes on the geography and natural history of Wake Island, by E. H. Bryan, Jr. 1-22, May 15, 1959.

67. Vegetation and flora of Wake Island, by F. R. Fosberg. 1-20, May 15, 1959.

68. Additional records of phanerogams from the northern Marshall Islands, by F. R. Fosberg. 1-9, May 15, 1959.

69. Contribution to a German reef-terminology, by Georg Scheer, 1-4, May 15, 1959.

70. Atoll news and comment, Editors. 1-7, May 15, 1959.

71. Microclimatic observations at Eniwetok, by David I. Blumenstock and Daniel F. Rex, with a special section on Vegetation by Irwin E. Lane. i-ix, 1-158, June 30, 1960.

72. Report on Tarawa Atoll, Gilbert Islands, by Edwin Doran, Jr. 1-54+24, Oct. 15, 1960.

73. Some aspects of Agriculture on Tarawa Atoll, Gilbert Islands, by R. R. Mason. 1-17, Oct. 15, 1960.

74. Birds of the Gilbert and Ellice Islands Colony, by Peter Child, 1-38, Oct. 15, 1960.

75. A report on Typhoon Effects upon Jaluit Atoll edited, by David I. Blumenstock. 1-105, April 15, 1961.

76. Observations on Puluwat and Gaferut, Caroline Islands, by William A. Niering. 1-10, December 31, 1961. Historical and climatic information on Gaferut Island, by Marie-Hélène Sachet. 11-15, Dec. 31, 1961.

77. A check list of marine algae from Ifaluk Atoll, Caroline Islands, by Isabella A. Abbott. 1-5, Dec. 31, 1961.

78. Narrative report of botanical field work on Kure Island, 3 October 1959 to 9 October 1959, by Horace F. Clay. 1-4, Dec. 31, 1961.

79. Botanical observations on Leeward Hawaiian Atolls, by Charles H. Lamoureux. 1-10, Dec. 31, 1961.

80. The tropical coral reef as a biotope, by Sebastian A. Gerlach, 1-6, Dec. 31, 1961.

81. Qualitative description of the coral atoll ecosystem, by F. R. Fosberg. 1-11, Dec. 31, 1961.

82. Heron Island, Capricorn Group, Australia, by F. R. Fosberg, R. F. Thorne and J. M. Moulton. 1-4, 5-13, 15-16, Dec. 31, 1961.

83. Notes on some of the Seychelles Islands, Indian Ocean, by C. J. Piggott, 1-10, Dec. 31, 1961.

84. Atoll News and Comments. Editors, 1-14, Dec. 31, 1961.

85. Land tenure in the Pacific - A symposium of the Tenth Pacific Science Congress convened by Edwin Doran, Jr. 1-60, Dec. 31, 1961.

86. Geography and land ecology of Clipperton Island, by Marie-Hélène Sachet. 1-115, Feb. 28, 1962.

87. Three Caribbean atolls: Turneffe Islands, Lighthouse Reef, and Glover's Reef, British Honduras, by D. R. Stoddart. 1-151, June 30, 1962.

88. Coral Islands, by Charles Darwin, with introduction, map and remarks by D. R. Stoddart. 1-20, Dec. 15, 1962.

89. Geophysical observations on Christmas Island, by John Northrop. 1-2, Dec. 15, 1962.

90. Plants of Christmas Island, by Alvin K. Chock and Dean C. Hamilton, Jr. 1-7, Dec. 15, 1962.

91. Central subsidence. A new theory of atoll formation, by Hans Hass. 1-4, Dec. 15, 1962.

92. Vascular plants recorded from Jaluit Atoll, by F. R. Fosberg and M.-H. Sachet. 1-39, Dec. 15, 1962.

93. A brief study of the cays of Arrecife Alacran, a Mexican atoll, by F. R. Fosberg. 1-25, Dec. 15, 1962.

94. Atoll news and comments, Editors, 1-19, Dec. 15, 1962.

95. Effects of Hurricane Hattie on the British Honduras Reefs and Cays, October 30-31, 1961, by D. R. Stoddart. 1-142, May 15, 1963.

96. Some aspects of the meteorology of the tropical Pacific viewed from an atoll, by Ronald L. Lavoie. 1-80, May 15, 1963.

97. The flora and vegetation of Laysan Island, by Charles H. Lamoureux. 1-14, Nov. 15, 1963.

98. Insects and other invertebrates from Laysan Island, by George D. Butler, Jr., and Robert L. Usinger. 1-30, Nov. 15, 1963.

99. Notes on the Wedge-tailed Shearwater at Heron Island, Great Barrier Reef, Australia, by A. O. Gross, J. M. Moulton, and C. E. Huntington. 1-11, November 15, 1963.

100. Atoll news and comments, Editors, 1-16, November 15, 1963.

101. Notes on Indian Ocean atolls visited by the Yale Seychelles Expedition, by Alan J. Kohn. 1-12, Sept. 30, 1964.

102. Notes on reef habitats and gastropod molluscs of a lagoon island at North Male Atoll, Maldives, by Alan J. Kohn. 1-5, Sept. 30, 1964.

103. Observations on the birds of French Frigate Shoal and Kure Atoll, by Miklos D.F. Udvardy and Richard E. Warner. 1-4, Sept. 30, 1964.

104. Carbonate sediments of Half Moon Cay, British Honduras, by D. R. Stoddart. 1-16, Sept. 30, 1964.

105. Floristic report on the marine benthic algae of selected islands in the Gilbert Group, by Roy T. Tsuda. 1-13, Sept. 30, 1964.

106. New records of Halimeda and Udotea for the Pacific area, by Edwin T. Moul. 1-10, Sept. 30, 1964.

107. Place names on Nukuoro Atoll, by Vern Carroll. 1-11, Sept. 30, 1964.

108. Atoll News and Comment, Issued by The Pacific Science Board 1-8, Sept. 30, 1964.

109. A preliminary list of the algal flora of the Midway Islands, by Richard G. Buggeln. 1-11, July 15, 1965.

110. Marine algae from Laysan Island with additional notes on the vascular flora, by Roy T. Tsuda. 1-37, July 15, 1965.

111. An annotated bibliography of recent papers on corals and coral reefs, by John D. Milliman. 1-58, July 15, 1965.

112. Atoll News and Comment, Issued by The Pacific Science Board. 1-14, July 15, 1965.

113. Terrestrial Sediments and Soils of the Northern Marshall Islands, by F. Raymond Fosberg and Dorothy Carroll. 1-156, Dec. 31, 1965.

114. Northern Marshall Islands land biota: Birds, by F. R. Fosberg. 1-35, March 31, 1966.

115. Marine benthic algae from the Leeward Hawaiian Group, by Roy T. Tsuda. 1-13, March 31, 1966.

116. Reef studies at Addu Atoll, Maldive Islands, edited by David R. Stoddart. 1-122, March 31, 1966.

117. Atoll News and Comments, Issued by The Pacific Science Board, 1-8, March 31, 1966.

Nos. 1-117 were issued by the National Academy of Science--N.R.C. The following issued under the sponsorship of the Smithsonian Institution, Washington, D. C.

118. Ecology of Aldabra Atoll, Indian Ocean, edited by David R. Stoddart. 1-141, Nov. 15, 1967.

119. Atoll News and Comment. 1-6, Nov. 15, 1967.

120. A Record of Benthic Marine Algae from Johnston Atoll by Richard G. Buggeln and Roy T. Tsuda. 1-20, March 30, 1969.

121. The Algae of Kapingamarangi Atoll, Caroline Islands. Part 1. Checklist of the Cyanophyta, Chlorophyta and Phaeophyta by Jan Newhouse. 1-7, March 30, 1969.

122. Marine Toxins from the Pacific II. The Contamination of Wake Island Lagoon by Albert H. Banner, Judd C. Nevenzel and Webster R. Hudgins. 1-9, March 30, 1969.

123. Wake Island Vegetation and Flora, 1961-1963 by F. R. Fosberg and M.-H. Sachet. 1-15, March 30, 1969.

124. Ecology of Terrestrial Arthropods on the Tokelau Atolls by Alden D. Hickley. 1-18, March 30, 1969.

125. Reconnaissance Geomorphology of Rangiroa Atoll, Tuamotu Archipelago by D. R. Stoddart with List of Vascular Flora of Rangiroa by Marie-Hélène Sachet. 1-44, March 30, 1969.

126. Island News and Comment. 1-19, March 30, 1969.

127. Ornithology of the Marshall and Gilbert Islands by A. Binion Amerson, Jr. May 28, 1969.

128. Notes on Birds Observed in the Comoros on Behalf of the Smithsonian Institution by A. D. Forbes-Watson. 1-23, Aug. 15, 1969.

129. Four Southwestern Caribbean Atolls: Courtown Cays, Albuquerque Cays, Roncador Bank and Serrana Bank by John D. Milliman. 1-26, Aug. 15, 1969.

130. A Botanical Description of Big Pelican Cay, a Little Known Island off the South Coast of Jamaica by C. D. Adams. 1-10, Aug. 15, 1969.

131. Post-Hurricane Changes on the British Honduras Reefs and Cays: Re-Survey of 1965 by D. R. Stoddart. 1-25, Aug. 15, 1969.

132. Plants of Satawal Island, Caroline Islands by F. R. Fosberg. 1-13, Aug. 15, 1969.

133. A Collection of Plants from Fais, Caroline Islands by F. R. Fosberg and Michael Evans. 1-15, Aug. 15, 1969.

134. Plants Collected on Islands in the Western Indian Ocean During a Cruise of the M. F. R. V. "Manihine," Sept.-Oct. 1967 by M. D. Gwynne and D. Wood. 1-15, Aug. 15, 1969.

135. Island News and Comment. 1-17, Aug. 15, 1969.

136. Coral Islands of the Western Indian Ocean by D. R. Stoddart. 1-224, Aug. 28, 1970.

137. Carbonate Sand Cays of Alacran Reef, Yucatan, Mexico: Sediments by Robert L. Folk and Augustus S. Cotera. 1-16, Feb. 16, 1971.

138. The Vertebrate Fauna and the Vegetation of East Plana Cay, Bahama Islands by Barrett C. Clough and George Fulk. 1-17, Feb. 16, 1971.

139. The Island of Anegada and its Flora by W. G. D'Arcy. 1-21, Feb. 16, 1971.

140. Inshore Marine Habitats of Some Continental Islands in the Eastern Indian Ocean by Alan J. Kohn. 1-29, Feb. 16, 1971.

141. The Distribution of Shallow-Water Stony Corals at Minicoy Atoll in the Indian Ocean with a Check-List of Species by C. S. Gopinadha Pillai. 1-12, Feb. 16, 1971.

142. The Uninhabited Cays of the Capricorn Group, Great Barrier Reef, Australia by S. B. Domm. 1-27, Feb. 16, 1971.

143. The Safe Use of Open Boats in the Coral Reef Environment by S. B. Domm. 1-10, Feb. 16, 1971.

144. The Vascular Flora and Terrestrial Vertebrates of Vostok Island, South-Central Pacific by Roger B. Clapp and Fred C. Sibley. 1-10, Feb. 16, 1971.

145. Notes on the Vascular Flora and Terrestrial Vertebrates of Caroline Atoll, Southern Line Islands by Roger B. Clapp and Fred C. Sibley. 1-18, Feb. 16, 1971.

146. Records of Mallophaga from Pacific Birds by A. Binion Amerson, Jr. and K. C. Emerson. 1-30, Feb. 16, 1971.

147. Rainfall on Indian Ocean Coral Islands by D. R. Stoddart. 1-21, Feb. 16, 1971.

148. Island News and Comment. 1-38, Feb. 16, 1971.

149. Geography and Ecology of Diego Garcia Atoll, Chagos Archipelago edited by D. R. Stoddart and J. D. Taylor. 1-237, Aug. 27, 1971.

150. The Natural History of French Frigate Shoals Northwestern Hawaiian Islands, by A. Binion Amerson, Jr. 1-383, Dec. 20, 1971.

151. Bacterial counts in surface open waters of Eniwetok Atoll, Marshall Islands, by Louis H. DiSalvo. 1-3, Dec. 31, 1972.

152. Marine studies on the North Coast of Jamaica, edited by Gerald J. Bakus. 1-6, Dec. 31, 1972.

153. Fish diversity on a coral reef in the Virgin Islands, by Michael J. Risk. 1-4, Dec. 31, 1972.

154. Recolonization of a population of supratidal fishes at Eniwetok Atoll, Marshall Islands, by William A. Bussing. 1-4, Dec. 31, 1972.

155. Some marine benthic algae from Truk and Kuop, Caroline Islands, by Roy T. Tsuda. 1-10, Dec. 31, 1972.

156. Additional records of marine benthic algae from Yap, Western Caroline Islands, by Roy T. Tsuda and Mary S. Belk. 1-5, Dec. 31, 1972.

157. Carbonate lagoon and beach sediments of Tarawa Atoll, Gilbert Islands, by Jon N. Weber and Peter M. J. Woodhead. 1-21, Dec. 31, 1972.

158. Birds seen at sea and on an island in the Cargados Carajos Shoals, by R. Pocklington, P. R. Willis and M. Palmieri. 1-8, Dec. 31, 1972.

159. Geomorphology and vegetation of Iles Glorieuses, by R. Battistini and G. Cremers. 1-10, Dec. 31, 1972.

160. Reef islands of Rarotonga, by D. R. Stoddart, With list of vascular Plants by F. R. Fosberg. 1-14, Dec. 31, 1972.

161. South Indian sand cays, by D. R. Stoddart and F. R. Fosberg. 1-16, Dec. 31, 1972.

162. Island News and Comment. 1-26, Dec. 31, 1972.

163. The natural history of Gardner Pinnacles, Northwestern Hawaiian Islands, by Roger B. Clapp. 1-25, Dec. 31, 1972.

164. The natural history of Kure Atoll, Northwestern Hawaiian Islands, by Paul W. Woodward. 1-318, Dec. 31, 1972.

165. Central Western Indian Ocean Bibliography, by A. J. Peters and J. F. G. Lionnet. 1-322, May 2, 1973.

166. Crown of thorns (Acanthaster planci) plagues: The natural causes theory, by Peter J. Vine. 1-10, Nov. 23, 1973.

167. A study of some aspects of the crown-of-thorns starfish (Acanthaster planci) infestations of reefs of Australia's Great Barrier Reef, by R. Endean and W. Stablum. 1-62, Nov. 23, 1973.

168. The apparent extent of recovery of reefs of Australia's Great Barrier Reef devastated by the crown-of-thorns starfish, by R. Endean and W. Stablum. 1-26, Nov. 23, 1973.

169. Investigations of Acanthaster planci in Southeastern Polynesia during 1970-1971, by Dennis M. Devaney and John E. Randall. 1-23, Nov. 23, 1973.

170. Population levels of Acanthaster planci in the Mariana and Caroline Islands 1969-1972, by James A. Marsh, Jr., and Roy T. Tsuda. 1-16, Nov. 23, 1973.

171. The natural history of Laysan Island, Northwestern Hawaiian Islands, by Charles A. Ely and Roger B. Clapp. 1-361, Dec. 31, 1973.

172. Comparative Investigations of Tropical Reef Ecosystems: Background for an integrated coral reef program. Edited by Marie-Hélène Sachet and Arthur L. Dahl. 1-169, Dec. 15, 1974.

173. Preliminary checklist of the marine benthic plants from Glover's Reef, British Honduras, by Roy T. Tsuda and Clinton J. Dawes. 1-13, Dec. 15, 1974.

174. The Natural History of Pearl and Hermes Reef, Northwestern Hawaiian Islands, by A. Binion Amerson, Jr., Roger B. Clapp, and William O. Wirtz, II. 1-306, Dec. 31, 1974.

175. Observations on the birds of Diego Garcia, Chagos Archipelago, with notes on other vertebrates, by A. M. Hutson. 1-25, Jan. 15, 1975.

176. The birds of the Iles Glorieuses, by C. W. Benson, H. H. Beamish, C. Jouanin, J. Salvan, and G. E. Watson. 1-34, Jan. 15, 1975.

177. Fulgoroidea from Aldabra, Astove, and Cosmoledo Atolls, collected by the Royal Society Expedition 1967-68 (Hemiptera-Homoptera), by M. D. Webb. 1-10, Jan. 15, 1975.

178. A preliminary description of the coral reefs of the Tobago Cays, Grenadines, West Indies, by John B. Lewis. 1-9, Jan. 15, 1975.

179. Marine zonation and ecology of Cocos Island, off Central America, by Gerald J. Bakus. 1-9, Jan. 15, 1975.

180. Biogeography of reptiles on some of the islands and cays of Eastern Papua-New Guinea, by Harold Heatwole. 1-32, Jan. 15, 1975.

181. Sand cays of Tongatapu, by D. R. Stoddart. 1-8, Jan. 15, 1975.

182. The murine rodents Rattus rattus, exulans and norvegicus as avian predators, by F. I. Norman. 1-13, Jan. 15, 1975.

183. Ducie Atoll: Its history, physiography and biota, by Harold A. Rehder and John E. Randall. 1-40, Jan. 15, 1975.

184. Marine turtles in the Phoenix Islands, by George H. Balazs. 1-7, Jan. 15, 1975.

185. Island News and Comment. 1-40, Jan. 15, 1975.

186. The Natural History of Lisianski Island, Northwestern Hawaiian Islands. 1-196, Feb. 15, 1975.

187. The Algal Ridges and Coral Reefs of St. Croix their structure and Holocene development, by Walter H. Adey. 1-67, Aug. 6, 1975

188. Anegada Island: Vegetation and Flora by W. G. D'Arcy. 1-39, Aug. 6, 1975.

189. The Natural History of Namoluk Atoll, Eastern Caroline Islands by Mac Marshall with identifications of vascular flora by F. R. Fosberg. 1-53, Aug. 6, 1975.

190. Almost-Atoll of Aitutaki: Reef Studies In The Cook Islands, South Pacific, Edited by D. R. Stoddart and P. E. Gibbs. 1-158, Aug. 13, 1975.

191. Bibliography of The Natural History of the Bahama Islands by William T. Gillis, Roger Byrne, and Wyman Harrison. 1-123, Aug. 20, 1975.

192. The Natural History of Johnston Atoll, Central Pacific Ocean, by A. Binion Amerson and Philip C. Shelton, Dec. 1976.

193. A photographic survey down the seaward reef-front of Aldabra Atoll, by Edward A. Drew, in press.

194. Topography and coral distribution of Bushy and Redbill Islands and surrounding reef, Great Barrier Reef, Queensland, by Carden C. Wallace and E. R. Lovell, in press.

195. Coral Cays of the Capricorn and Bunker Groups, Great Barrier Reef Province, Australia, by P. G. Flood, in press.

196. Submarine cementation of grainstone fabric, St. Croix, U. S. Virgin Islands, by Lee C. Gerhard, in press.

197. Christmas Island (Pacific Ocean): Reconnaissance geologic observations, by Mark J. Valencia, in press.

198. Notes on the vertebrate fauna of Tongareva Atoll, by Roger B. Clapp, in press.

199. Observations on vegetation of blue-faced booby colonies on

Cosmoledo Atoll, Western Indian Ocean, by Mary E. Gillham, in press.

200. Vegetation of sea and shore-bird colonies on Aldabra Atoll, by Mary E. Gillham, in press.

201. Life history notes on some Aldabran land birds, by C. B. Frith, in press.

202. Climate of Aldabra Atoll, by D. R. Stoddard and L. U. Mole, in press.

203. Annotated check list of corals in the Mascarene Archipelago, Indian Ocean, by Gérard Faure, in press.

204. Annotated check list of octocorallia in the Mascarene Archipelago, Indian Ocean, by Gérard Faure, in press.

205. The hosts of the Coral-Associated Indo-West-Pacific Pontoniine shrimps, by A. J. Bruce, in press.

206. The Natural History of Necker Island, Northwestern Hawaiian Islands, by Roger B. Clapp and Eugene Kridler, in press.

207. The Natural History of Nihoa Island, Northwestern Hawaiian Islands, by Roger B. Clapp, Eugene Kridler, and Robert R. Fleet, in press.

208. Notes on plants of the genus Caulerpa in the Herbarium of Maxwell S. Doty at the University of Hawaii by Wm. Randolph Taylor, in press.

209. Marine algae of the Te Vega 1965 expedition in the Western Pacific Ocean, by Wm. Randolph Taylor, in press.

210. Marine algae known from the Maldive Islands, by H. E. Hackett, in press.

211. The benthic algal composition standing crop, and productivity of a Caribbean algal ridge, by Judith L. Connor and Walter H. Adey, in press.

212. Preliminary observations on the algae, corals, and fishes inhabiting the sunken ferry "Fujikawa Maru" in Truk Lagoon, by Roy T. Tsuda, Steven S. Amesbury, and Steven C. Moras, in press.

213. Chemistry of freshwater pools on Aldabra, by A. Donaldson and B. A. Whitton, in press.

214. Observation on redox potential in freshwater pools on Aldabra, by B. A. Whitton and M. Potts, in press.

215. Algal flora of freshwater habitats on Aldabra, by A. Donaldson and B. A. Whitton, in press.

216. Terrestrial and freshwater algae of three Western Indian Ocean

Islands (Astove, Farquhar and St. Pierre), by B. A. Whitton and A. Donaldson, in press.

217. Terrestrial and swamp algae from three islands in the Chagos Archipelago, Indian Ocean, by B. A. Whitton, A. Donaldson, D. J. Bellamy, and C. Sheppard, in press.

218. The Holocene reef systems of eastern Martinique, French West Indies, by Walter H. Adey, Patricia J. Adey, Randolph Burke and Leslie Kaufman, in press.

219. Island News and Comment, in press.

U. S. GOVERNMENT PRINTING OFFICE : 1977 O - 231-339